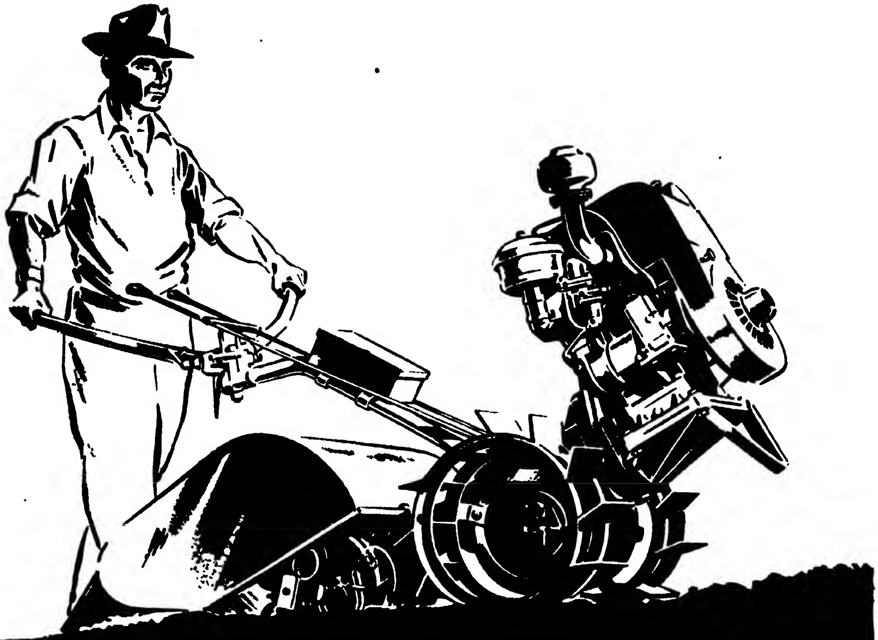

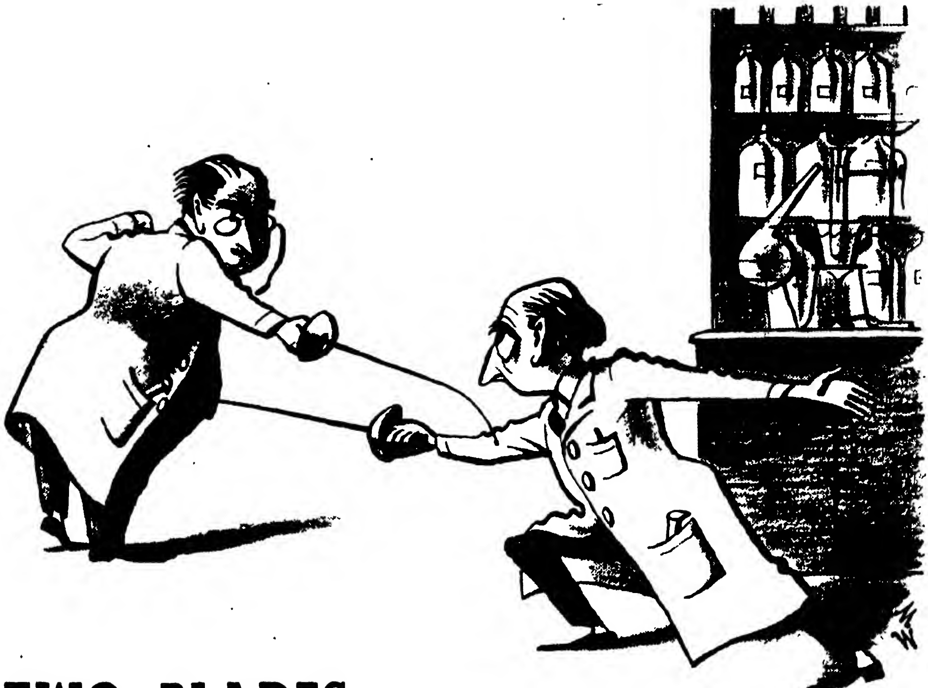

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Hon. Editor: R. T. PEARL, M.Sc., A.R.C.S., D.I.C.
University of Nottingham School of Agriculture
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EDITORIAL

The decision, in September 1939, to discontinue the publication of *Scientific Horticulture* during the war emergency was made most reluctantly. At the time it could not be foreseen how many difficulties would arise before regular publication could start again. It was, therefore, with especial pleasure that we announced in March 1947 that arrangements had been made with Messrs. Jarrold & Sons to recommence publication.

And here at long last is our first post-war volume—with its "New Look" cloth cover—but we think with the same authentic contents surveying the science and progress of horticulture—which earned for *Scientific Horticulture* its popularity with growers and educationists alike. This time we hope its reappearance will herald an unbroken line of regular and increasingly interesting volumes, which as a grower friend of ours recently put it—"is a mine of information on modern research and development, which no one in the horticultural industry can afford to be without".

Readers with long memories may wonder why this volume is called Volume IX, since the last pre-war issue was Volume VII. The explanation is quite simple. During the war years and after we were only able to issue a very restricted edition of *Occasional Publications on Scientific Horticulture* (Nos. 1–5, 1939–47) for the information of our members and other regular subscribers in Great Britain. Limited paper supplies and other restrictions prevented us from printing enough copies to satisfy overseas subscribers and readers returning from war service. Sooner or later when paper supplies permit, we hope to re-issue these five numbers in a special omnibus edition of one complete volume. When this is done the intention is to call the combined volume *Scientific Horticulture*, Vol. VIII (1939–47), thus linking the pre-war issues ending with Vol. VII (1939) with the new post-war issues commencing with Vol. IX (1948).

The rapid strides made in horticultural research are well illustrated by the present volume. Its main theme is the first post-war Refresher Course in Horticulture held in September 1946. The unavoidable delay of two years in its publication has necessitated supplementary articles to cover recent progress in some subjects, whilst in others we expect to review progress again next year. Time was when a review in *Scientific Horticulture* might have been the last word on the subject for a good ten years.

Be that as it may, *Scientific Horticulture* returns with its continuity in the future assured, and from the remarks of our contemporaries it is clear that there is a special welcome for us in the field of horticultural literature—a fact made self-evident by the generous appreciation and help of our very good friends, the Horticultural Press.

FOREWORD

to the Revision Course in Horticulture, 1946

A "REFRESHER" course suggests at once a course to recall things that have been forgotten. The "refresher" course held at the Midland Agricultural College during September, 1946, was not of this kind for it was designed to treat of fresh horticultural knowledge gained during the war period.

On the outbreak of war many horticultural workers were divorced from technical horticultural work. Some went into the Services, some into factories, many to do purely executive work as Labour Officers, Machinery Officers, District Officers and only a few remained on technical work. Wherever they went most were fully engaged on immediate work and had little leisure time available to seek out and follow the research activities or to study and absorb the results achieved. In consequence many people reached 1946 with the horticultural knowledge of 1939, even though much progress in horticulture had been made during the period.

The problems of food production that arose during the war period proved a great stimulus to research work and much progress was made with research in the horticultural field. Fertilisers were in short supply and yet more land had to be kept cropped than formerly. Additional knowledge was acquired concerning the making of composts and its use in improving soil fertility: there was an advance of knowledge as to the mineral requirements of plants, particularly of lime, potash, phosphates and the minor elements such as magnesium, manganese, boron. Almost a new chapter was opened concerning deficiency elements and their effect on plant growth. Plant growth substances as distinct from mineral also received much attention.

Before 1939 plant hormones were known, but since then it has been shown that selected synthetic chemicals can equally supply a stimulus to plant cells. It was shown also that when used at higher concentrations these growth-promoting chemicals so thoroughly disorganised the growth of some plants without affecting others, that they could play the role of selective weed-killers.

It was a period, too, when the chemist fought strenuously to introduce insecticides of greater merit than those previously used in horticulture. They succeeded and so important are these new insecticides to the horticultural growers that the textbooks on insect control may have to be rewritten.

Thus in many fields much progress was made between 1939 and 1946, and those who had been out of touch with horticulture felt themselves at a disadvantage. The course at the Midland was designed to remove that handicap and I expect it did so.

The papers, now printed in book form, should reach many who were unable to take the course and should prove a boon and a blessing to them. The report should be especially useful to those who have returned to horticulture after a period of four or five years' absence with the Services and who naturally feel a wee bit rusty in some subjects.

H. V. T.

HORTICULTURE IN THE N.A.A.S.

by

H. V. TAYLOR, C.B.E., D.Sc., A.R.C.S., V.M.H.
(Senior Advisory Officer, Ministry of Agriculture and Fisheries)

THE National Agricultural Advisory Service has been created to give assistance and technical advice to those seeking to obtain a living from the land. This Service will perform an old task in a new way, and everybody should realise the differences between the old method and the new.

The reason for the change came as soon as it was realised that much more food had to be produced from British soil and growers should be given more advice and assistance. This was not a task that County Councils could be expected to perform, but was a national matter to be dealt with in a national way. As a result the War Agricultural Executive Committees were established, and stage by stage these Committees (as agents of the Ministry) assumed responsibilities of diverse characters including that of giving advice and assistance to the growers.

For these purposes the Committees built up teams of workers partly by borrowing staff from County Councils and partly by direct employment, so that over the country as a whole there seemed to be little orderly arrangement.

The work, however, was successfully done, the food was produced, the growers received the advice and indeed displayed such craving for technical advice and for the results of research and experimental work as to astonish those who were appointed to give it. Some people in high quarters marked the success of this new system and were reluctant to see it lightly abandoned.

The Luxmoore Committee

The upshot was the appointment of a Committee under the chairmanship of the Rt. Hon. Lord Justice Luxmoore, P.C., to examine the system of Agricultural Education in England and Wales and to make recommendations for improving and developing it after the war.

This Committee recommended the creation of a new National Agricultural Advisory Service embracing specialists, scientists, and also such as were qualified to deal with husbandry problems. In the Committee's view the prime object of the Service must be to provide that every farmer in the country, whether he carries on his business on a large or small scale, should have easy access to the best and most up-to-date practical and scientific advice available. This object is most likely to be obtained if each county is divided into districts, each under the control of a district

This paper was read at the Revision Course in September 1946 and deals with developments at that time.

officer. The district officer must be able to advise and help the farmer in any ordinary difficulty experienced in the carrying on of his business. He should be trained in agricultural science and should have a sound knowledge of the art and practice of agriculture. He should be provided with an office to serve as an information bureau for the farmers in his district; and suitable accommodation should be available for the holding of meetings of farmers, for demonstrations, lectures and discussions.

The next unit in the Service should be the county, which should be administratively in charge of a county organiser. His duty should be to direct and co-ordinate the work of the several district officers in his county, to deal with the advisory problems submitted by the district officers and, where necessary, to forward them to the appropriate specialist officers.

In addition to the district officers, the county organiser should have a staff of assistants specially qualified in such subjects as dairying, poultry-keeping and the use, maintenance and repair of farm machinery and competent to give instruction and advice in such subjects.

The District Officer

To tone in with the growers in any particular area the district officer will have to be selected carefully so that each possesses a knowledge of the agricultural and horticultural features special to each district. A live-stock man for a stock district, a crop man for arable districts, a dairying man for dairy districts, and likewise a fruit or vegetable man for fruit and vegetable districts. These district officers will have to be organisers of committees, of farmers' meetings, leaders of development and enterprise, friends of the grower and with sufficient general knowledge of soils and crops to enable them to call into the problem the appropriate specialist adviser from county or provincial headquarters. A district officer should be a good organiser and have a wide general knowledge.

It is extremely doubtful whether there are sufficient people of this character available at present to fulfil all these tasks adequately, but undoubtedly the young men now entering the Service will train to perform these tasks with distinction.

The Horticultural Advisory Officers at county level and the Specialist Advisers at provincial level will be called upon to display greater technical knowledge of commercial husbandry than hitherto. Indeed as the district officer assumes more and more responsibility for organisation work there will be a corresponding need for the adviser to concentrate more and more on the technical side.

One Service for both Agriculture and Horticulture

You will have noticed that the Luxmoore Committee made special recommendations for horticulture tantamount to the establishment of a separate advisory service for horticulture. This recommendation was not accepted by the Government. It was laid down, however, that there would

be one service for all growers, but that in its creation horticulture would have its proper recognition.

To secure this it meant that at every level posts would be open to horticulturally trained people. In other words, that in addition to the specialist horticultural advisers there should be horticulturally trained people as organisers in charge of those districts, counties and provinces where horticulture cropping was a prominent feature. If this was arranged then chances of acquiring or gaining administrative experience and avenues of promotion would be opened up for the horticultural staff that should bring to the horticulture service young men of high ability and enterprise.

A Service that contained horticultural advisers denied of the other advantages mentioned would remain too unattractive to recruit the best brains, the horticulture side would remain small and become incapable of providing the industry with the service it will surely need.

One Team for all Tasks

In the past certain features of horticulture lay outside the function of the county adviser and had become that of the Ministry's inspector. This could hardly continue indefinitely. The grower seeks advice concerning certified stocks for planting of potatoes, strawberries, blackcurrants, raspberries, etc., he also needs to have his crops examined by fully qualified people—to acclaim their standard of health and purity. It is sensible to have such technical work done by the technical advisory staff and not for the Ministry to create another technical staff for the purpose.

Reports of crops and crop prospects are always needed, and it is generally agreed that the people most fitted to give these reports would be the technical staff in the areas concerned. It is good, too, that members of the Service should interest themselves intimately with acreages and yield of crops in the areas under their control, for such statistics are fundamental to the giving of good advice. In the past pest and disease control has not been the affair of the adviser. Experience has shown that for this work a trained staff is needed—entomologists, mycologists and people who understand the crops involved. No one knows this better than the horticultural advisers who have administered any local orders in their particular counties.

All the available entomologists, mycologists and horticulturists have been welded into the N.A.A.S., and the Service is obviously able to perform this task.

Thus we reach the stage that the horticultural members of the N.A.A.S. will be responsible for all technical horticultural work affecting crop production in their area.

This will be an important change to many, for the work will embrace:

Advisory work to growers, the technical supervision of services to growers.

The inspection of crops of potatoes, strawberries, blackcurrants, raspberries, hops and fruit-tree stocks.

Certification of seed potatoes and plants for export, as well as helping in the campaign to control Colorado beetle and other noxious pests.

There will be one horticultural team for all these jobs.

This could not happen at once. The county adviser is skilled in giving advice; the Ministry's inspector has become a master of great knowledge and experience at crop inspection work; and for a time each will continue to do his particular task. Training will begin and in time each county horticultural or district officer would become capable of carrying out all types of work with equal confidence. Indeed he must do so or be prepared to see someone come into his area to do the job—an affair always unpleasant though often tolerated.

In addition to this trained staff the County Agricultural Committee will need people with some horticultural knowledge and experience for routine services, possibly in connection with fruit-tree spraying, soil sterilisation and other services. Such staff would be temporary members of the Committees and not permanent members of the N.A.A.S.

The Special Adviser

So much for the county organisation, but that by itself would not be a sufficient service for the horticultural industry, and particularly for the industry to, say, 1950 and onwards. The industry now comprises farmers who grow horticultural crops, market producers of a large variety of horticultural crops and in addition growers who specialise in particular crops. Amongst others there are those who specialise respectively in fruit growing, flower growing or in crop production under glass. The skill possessed by these men in their respective industries has reached a very high level, and it might be thought that few would require advice from outsiders. Experience has shown that the contrary is true and that the more specialised in production a grower becomes the greater his demand for advice, but usually for advice of a very specialised kind, and in past years he has directed his inquiries much too frequently to the staff at the research stations. The measure of these inquiries is given in the annual reports of the horticultural research stations. In many ways it may be a good thing for the growers to seek advice direct of the research workers, but there is also a debit side; for the research programme becomes disrupted and the workers' thoughts that should be concerned with research problems also become diverted to other channels.

The amount of advisory work done by some horticultural stations has undoubtedly slowed down the rate of progress made with the research programme. Provision must therefore be made in the Service for a team of specialists capable of giving the industry that assistance at present obtained from other places. The N.A.A.S. must have specialists in fruit growing, specialists in vegetable production, specialists in flower production and specialists in crop production under glass. Now, specialists are

like rare plants: they are few in number and difficult to find. Indeed, when they are discovered they must serve an area as large as a province rather than a county. Even so, the number of specialists at present available is too few to appoint the full complement. Arrangements have been made to appoint six specialists in fruit production and a lesser number respectively in vegetable production and crop production under glass. The appointment of specialists in flower production can well be made at a later date, particularly when such specialists have emerged into the limelight and flower growing has taken a more essential place in our lives.

These specialists in their respective subjects must secure a close working arrangement with the appropriate research stations, be constant observers of all research work and quick to encourage the application of promising research to commercial practice. In collaboration with the research stations the provincial specialist will become responsible for extended experimental work done in the province.

They are in no way responsible for the county staffs, their organisation or work, but they should take pains to encourage team work amongst the horticultural staff in each province so that the advice given in all areas and by all personnel is of the proper and approved kind.

Specialist Groups

As a link in this organisation it is proposed that the appropriate specialists should come together to form a group, thus there will be a fruit group, a vegetable group and a glasshouse group.

Each group would be based on the appropriate research station, and it is hoped that the director of the appropriate research station will become chairman of each group. The group would become responsible for official bulletins, leaflets for extended field experimental work, variety trials, as well as for agreeing on the advice to be given in special subjects. These men will be connected on the one side with the research station and on the other with the county staff and the industry, and so should have constantly under review the rate at which research results are applied in commercial practice.

That is the picture, but its full application to practice must await the emergence of a sufficient number of real specialists. Those at the head of the Service must be watchful of the staffs wherever placed, quick to recognise potential future specialists, procure facilities for each member of the staff to move forward to that branch of the Service for which he is most fitted and provide a proper ladder of promotion for members of each type.

Horticultural Experiment Stations

There is another side of the Service to which brief reference must be made, and that concerns the gathering of reliable advice based on research and experimental work on each subject to be handed on to the industry by members of the Service. This means that the research facilities

must be widened and a system of field experimental work planned. Let us for a moment survey the field. Research with fruit growing is already provided for. A research station for crops under glass exists, but its size is too limited to tackle all crops and an expansion is desirable. A station for vegetable research is an immediate proposition, and at the appropriate time a station for flowers, bulbs, flowering and decorative trees and shrubs would be a great asset to a large and important industry.

One station for each subject will do much for these industries, but these stations can carry out research on one type of soil and under one climate, and it is manifestly desirable that these stations should possess facilities for conducting extended work on other soils and other climates.

Similarly, there are large areas of the country remote from any research station where growers possibly may not have become as conscious of research as those nearer at hand to a station. For these two reasons it has therefore been agreed that a number of experimental horticultural stations should be established. For the present one is suggested for the north, one for the Midlands, one for East Anglia, one for the southern counties and one for the West of England. Such stations would have 100 acres or so of land equipped with field laboratories and deal with horticultural crops of importance to the areas served.

They would come within the ambit of the N.A.A.S. and be staffed with N.A.A.S. staff. The field experimental work would be organised by the provincial horticultural specialists in close association with appropriate research stations concerned. Such stations would also do purely local research and serve as extended stations for the main research stations.

The Future

I have dealt with the present, but what of the future?

The horticultural industry is sure to expand and consequently the horticultural side of the Service must increase. In the next few years we must therefore have ready to hand men of ability and efficiency who can assume responsibilities in the provinces, counties and districts in a greater measure than is possible at present.

We must remind ourselves, too, that it is not an easy matter to weld into one Service staff of a dissimilar character drawn from universities, colleges and the Ministry and to expect the various members to act as a perfect team during the first few weeks. The Service will take time to bed down. As soon, however, as the members of the Service learn to act as a team, it should be able to help the industry forward to that greater efficiency which must be the goal of all.

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SOIL SURVEYS

by

A. MUIR, Ph.D.
(Soil Survey of England and Wales, Rothamsted Experimental Station, Harpenden, Herts.)

In Britain the development of soil survey has been slow, although the soil texture map of Aberdeenshire published in 1812 must be one of the earliest of soil maps. Texture dominated the soil maps of both Britain and the U.S.A. for long after the Russians had enunciated the idea of soil as a natural body with a well-defined morphology. Thus, we have in this country the classic survey of Hall and Russell, and those of Luxmoore, Robinson and others during the first decade or so of this century—all based on the texture of the surface soil coupled with the parent rock or material. It was only in the twenties that the Russian ideas became generally known in this country and what we might call the era of soil profiles began. At this time, too, there was a move to institute a proper soil survey organisation, but nothing was done; and the work of carrying out soil surveys was left to the advisory chemists for the most part. Progress was naturally slow, and it was not until just before this last war that a definite step was taken to unite the soil survey work under Professor G. W. Robinson. With the reorganisation of the advisory services the survey is being brought under the Research Branch directed from Rothamsted. We hope that steady progress will now be made in the development of the survey.

Soil Classification

As I have said, the earlier maps were based on geology or on texture; the Russians added the climatic factor; and our present-day maps are what might be called a combination of all three. The essential point to bear in mind is that any soil is a reflection of the effects of all the factors in a natural landscape. It is obviously impossible to arrive at a satisfactory classification or grouping of soils until all their features are known, and modern soil mapping is based upon soil profile. This is simply the vertical section of a soil, from the surface down to the material from which the soil was derived—the weathered solid rock or drift. In other words soils are mapped on the basis of their field characteristics down to a depth of some 3 to 4 feet.

Since the basis of our soil classification is the climatic soil type which is only well displayed under natural conditions, a short description of those occurring in this country may not be out of place. The first and probably most important of these soils is the podzol that we find under Calluna heaths and coniferous woodlands. The chief morphological features of the podzol type are the presence of a bleached or grey layer

Paper read at Revision Course in September 1946.

under the surface humus layer. The grey layer is followed by a rusty brown or ochreous layer that may or may not be strongly indurated. Cultivation destroys some or all of these features, and we find all transitions from soils with a marked bleached layer to soils with an almost uniformly coloured profile. This character of uniformity in colour is the feature of the Brown Earth group of soils which is found under well-drained broad-leaved woodland. Whereas the podzolic soils of this country are strongly acid, the brown earths are usually only slightly to moderately acid. They do not contain any free carbonate, except perhaps towards the base of the profile. This group is usually subdivided into soils of high base status, which are derived from base-rich parent materials, and soils of low base status. This division is not always possible in the field unless one tests the pH of the soil.

Associated with these two main groups of soils are the various types which are subject to high moisture conditions for considerable parts of the year or permanently. These are the *gley* soils of the surveyor. Depending on the moisture content gleying is first of all shown up by rusty spotting and later by bluish or greenish mottling or even whole layers coloured blue or green. It is convenient both from a pedological and practical viewpoint to subdivide the gley soils into two groups—(*a*) surface-water gleys in which the excessive water is in the surface, the lower layers perhaps being quite well drained; and (*b*) ground-water gleys in which the surface soil may be quite dry, at least seasonably.

It is to be expected that there are a great number of intermediate varieties between the well-drained podzol and brown earth and the gley group. Thus there may be gley podzolised and peaty gley podzolised, gleyed brown earths and so on.

Where the effect of geology is most pronounced is in the group of calcareous soils, which are base saturated to the surface and usually also contain much free carbonate. The main representatives of this group are the grey calcareous soils or rendzina, formed on chalk and the red and brown calcareous soils formed on hard limestone.

Lastly there are the group of peats—raised moss, basin peat, including fen, and other varieties.

While these large soil groups, or World groups as they are often called, represent the first stage or order in the classification of the soils of this country, one must use still further subdivisions or *series* of soils in order to make large-scale mapping possible. Another factor which necessitates this finer subdivision is, of course, human utilisation.

The soil series consists of all those soils which have nearly the same profile. This means, of course, that they are formed under very similar conditions with the same or similar parent material. These series are given locality names—frequently the name of the place where they were first found extensively. Thus we have Powys, Sion, Goldstone, Bridgnorth and so on. Variations in the texture of the surface soil give rise to types within a series and we can have, for example, Powys silt loam

or Powys loam. It is obvious that the texture cannot vary much within a series, otherwise the general profile characters will also differ and give rise to new series.

While the scheme of subdivision I have outlined is the standard one in this country and the United States, other methods are followed. One of these originating in Canada has been employed with success in Scotland. In essence it takes as the basis of classification the drainage properties of the soil. If one examines an area of uniform parent material one usually finds that the well-drained soils are confined to the higher elements of relief, whilst the ill-drained are in the hollows. This arrangement was called a catena by Milne in East Africa and an association by Ellis in Canada. The advantage of recognising such catenas or associations is that mapping is facilitated—a matter of some importance if one is making reconnaissance maps or is working in difficult country.

The identification of a soil series is not a simple matter, and quite a number of characteristics have to be considered. It may be useful to summarise these.

Soil Colour

The first point that strikes one in examining a soil profile is the colour of the various layers or horizons. This colour, especially in the deeper layers, is often an inheritance from the parent material. Thus soils on Old Red Sandstone are usually red; on clay-with-flints they are brown; chalky soils are grey. But quite often marked changes in colour take place as a result of soil development. I have already mentioned the formation of a bleached grey layer in the podzol, with its lower horizon of rusty brown. In the case of the chalky boulder clay, London clay, and some clays derived from shaly rocks, the initial colour of the parent material is blue or grey, whereas the upper parts of the soil are often brown. This last change in colour is due to the access of air to the soil and the subsequent oxidation of ferrous iron compounds. In other cases, owing to a development of waterlogging after the parent material was formed, we find that the reverse change has occurred, and that the reds of Old Red Sandstone or Triassic formations and drifts may become blue-grey or greenish at some depth. Hindrance to drainage may also influence the colour of the surface soil by its effect on peat formation.

Soil Texture

The second character usually considered is that of texture. The distribution of the soil particles among the various size groups is determined for the most part by the parent material, but subsequent soil-forming processes may have quite a profound effect by leaching the clay and other constituents from the surface to the subsoil. Texture is usually one of the main controlling factors in land utilisation and is thus accorded an important place in soil survey studies. In fact, the soil type, which forms the unit of classification, or species, in both the American and English

classifications, is based on texture. The number of kinds of texture one can recognise on a laboratory basis is legion, but in the field where one is dependent on one's sense of touch a limit has to be set. For practical purposes we recognise about a dozen textures in this country, although the Americans claim to be able to differentiate 21 varieties by the 'spit-and-rub' method. Some of these distinctions, however, have only limited practical significance. In the naming of textures one usually tends to follow local custom to some extent for no generally accepted nomenclature is available.

Soil texture cannot be altered appreciably, although it is possible that the heavy dressings of marl to sandy soils in the past may have affected their texture to some extent. It would be a very big task to lighten a heavy soil by the addition of sand. Stones are not included in textural names except in adjectival form to denote phases. But stoniness is an important feature and note is made of it.

Soil Structure

Colour and texture in well-drained soils, as mentioned above, are often, if not usually, a direct legacy from the parent material; but the next two points to be considered are secondary and result from the varied natural and human influences on the soil. The two characters are structure and consistence, which together give tilth. Both structure and consistence are dependent on texture and, in the upper layers, on the amount of humus and the lime status.

By structure is meant the shape of the aggregates into which a soil will break when allowed to dry out or when tossed from a spade. For aggregates to form at all there must obviously be a certain minimum amount of clay, silt or humus, but whether this will bind the coarser grains into aggregates will depend on the amount of lime present. It is apparent that soil conditions, such as air and water movement and heat transference, will be much affected by structure, and cultivation will have a strong influence on this. The compaction of a light soil or the loosening of a heavy one is merely a change in the arrangement of the soil grains and in the physical relationships of the finer clay particles.

From the standpoint of size and arrangement of particles three structures can be recognised in arable soils: (*a*) single grain, (*b*) cloddy, (*c*) crumbly or granular.

The single grain structure is shown by blown sands and by badly leached or overworked soil when it dries out—the type of structure that has led to the vast erosion problem that so many countries are now facing. In a cloddy structure the particles are so closely packed together that they are difficult to separate, and when the clod dries out it might as well be a lump of cement. In the third structure the binding of the particles is firm, but not excessive, and even when dry the crumbs are easily broken.

The crumb structure is the one most readily associated with the loam class of textures, in which it is easily developed, for it is in this class that

we have the most suitable mixture of coarse and fine particles. The crumbs are open and porous and permit the ready entry of air and water. Roots can ramify with freedom and the animal population finds a congenial home.

The shape of the aggregates is usually a characteristic of the different layers or horizons into which a soil can be divided. Thus in a broad-leaved woodland soil under well-drained conditions the upper layers usually have a crumb or granular structure, whereas the subsoil is usually what is called nutty—the aggregates are slightly more angular than in crumbs and distinctly harder. In wet, heavy soils, the subsoil usually breaks into inverted wedge-shaped aggregates which have a distinctive grey glaze on their surfaces. The surface soil in such a case breaks into irregular clods. In moorland and heath soils where the top soil is of the bleached type we often find a distinctly platy structure. Altogether one can recognise about a dozen well-defined structures which can be associated either individually or in combination with various soils and conditions.

Soil Constitution

What is generally called soil constitution covers characters like consistence, porosity and compaction, the last being either inherited from the parent material or secondary. Consistence is the term used to denote the cohesion of the soil mass and its resistance to the breaking up of the aggregates under handling pressure. The words used to describe consistence are those of everyday usage, like brittle for a soil that breaks with a clean fracture; plastic for one that bends rather than breaks, while a mellow soil is the aim of all cultivators. Naturally the consistence varies considerably with the moisture content of the soil, and one that is plastic when wet may be brittle when dry.

Porosity is a self-explanatory term, although the origin of some of the curious fissures and cavities one finds is not easy to explain. The larger holes and channels one sees are usually of animal origin, while the small, fine ones are due to former fine roots. Cracks are probably due to shrinkage of the clay material during dry weather and fine fissures may be due to the formation of the structural aggregates. Some fine holes are due to the dissolution of easily soluble substances such as calcium carbonate.

Compactness in a soil, such as one on boulder clay, may be primary, but in most cases it is a secondary phenomenon, as with plough pan. A characteristic which may have effects similar to that of simple compaction is cementation or induration. In this case the compaction is due to the infiltration of such substances as clay, iron and other oxides, calcium carbonate or humus. These substances may be washed down from the upper layers or be introduced by lateral or ground-water movement. The rusty-coloured subsoil in heath and moorland soils can attain an extraordinary degree of compactness and become quite impervious to water. Roots cannot penetrate it and grow laterally along its surface. While clay pan is rarely so hard, it is just as efficient in holding up surface water.

Soil Depth

One characteristic that would actually be noted at once in the examination of a soil profile is the depth. This is a term of purely agricultural origin and significance, for the student of soils considers the soil to extend from the surface right down to the parent material and so includes layers that the agriculturist gives little attention to. The customary meaning of soil depth is the depth to which humus has penetrated or what the soil man calls the 'A horizon', or the depth to which main root development has taken place.

Soil Mapping

In making a soil survey the first task of the surveyor is to become familiar with the various soil-forming factors and with the general agricultural practice of the district. During a rapid reconnaissance he will make notes on the various soil types he encounters. For detailed primary survey the 6 inches to 1 mile Ordnance Survey maps are used and the ground is covered field by field, the boundaries of the soils being established by digging pits and making auger borings. As the work proceeds, the surveyor records on his map symbols for the different soils and gradually delimits each soil. He is aided in this by the various surface features and by changes in the vegetation where this is natural.

Soil types are unfortunately not sharply defined units, but merge imperceptibly into each other and so the accuracy of mapping is bound to be somewhat variable. Allowing for the narrow transition zone from one soil to another, it is normally possible on agricultural land to map to within a few yards. On forest land or rough hill grazing the establishment of position is more difficult and the accuracy of the map is somewhat less.

The rate of soil survey on the 6-inches scale is relatively slow. Given good weather a surveyor can map some 40 sq. miles in a season. In order to speed up the production of useful, though less accurate, maps, reconnaissance surveys on the scale of 2½ inches to 1 mile are now being made in a number of areas.

In order to have fairly complete information about each soil type a set of profile samples is collected from a number of sites for laboratory study. The data obtained include mechanical composition, base status and nature and amount of the exchangeable bases, porosity and so on. In time it may be possible to make a systematic study of the nature of the clay fraction and the trace element content of the various soil series identified. These additional items should be of considerable value in research problems.

Soil Evaluation

On account of the apparent slowness of soil surveys there has been developed the alternative of so-called land-fertility maps. These have little claim to scientific basis and their use is strictly limited where they are not definitely misleading. The definition of fertility is not a simple

matter, since so many factors are concerned. In general one is confined more or less to descriptive terms in evaluating the various factors, for some essential data, such as water relationships, are not readily obtained. Again, we possess very little data on porosity, aggregation and the like for our different soil types. Methods do exist for the measurement of some of these properties, and we hope some time to have sufficient information to enable us to correlate these properties with productivity if not with fertility. Even so, one or two studies of soil type and crop performance have been made with interesting results.

It has been quite clearly shown that one ought to consider subsoil conditions on an equal footing with top-soil. By subsoil is meant not just the layer immediately below plough depth, but a depth of up to 3 feet. When one considers that the roots of an ordinary agricultural crop may penetrate even beyond this, the justification for keeping the deeper layers in mind is readily seen. It is invariably in the deeper layers that compaction and cementation occur, and there is always the possibility of heavier textured layers occurring at depth. There is little doubt that the unexplainable differences that sometimes occur in manurial trials are due to differences in the deeper parts of the soil which cannot be brought under control like surface soil and the amounts of fertiliser added.

Attempts have been made from time to time to put the field characters to some practical use in assessing what one might call natural fertility as against productivity which can vary with treatment. The method has been extensively used in Germany and Hungary, and a study of its possibilities is being made in this country.

What the scheme amounts to is this: one evaluates the land on the basis of points awarded after an examination of the various soil factors. In the final analysis, of course, one has to consider climate, crops and transport, as well. Taking soil alone for the moment, one system works roughly in this way; loams get 30 points, sandy loams 20, sands 9. A very good crumb structure would get 10 points, a poorer one 5. The subsoil is then considered and one with a good open structure is awarded 15 points and so on down the scale to a bad subsoil which gets only 3 points. Soil moisture is treated in the same way and also the topography and the state of cultivation.

The total possible points for soil conditions in the scheme is 90. With a similar scheme of marking for climate and economics of transport, the total for a perfect region is 120 points. The different areas are graded according to their marks which can be compared with rentals or land values, in terms of money.

Such schemes are not entirely satisfactory since they have more of a regional character, and the system of points is somewhat arbitrary and leaves a good deal to be desired. In a country like this we have already a pretty long experience of what regions are most suited to various crops, and what we require is a simple method of evaluating potential fertility of individual soils. At the moment that does not exist. Nevertheless,

some method such as I have described could be developed and, together with chemical analysis for the nutrient status, it would form a useful means of estimating fertility.

Correlation with Crop Performance

Of course, one can say that the obvious method is to take crop yields, but that method can only be used when it is known that the soil is getting the best possible treatment or under experimental conditions where the variations in treatment are under control.

As an example of the use of crop yields as a guide to fertility I can quote some results given by Sir John Russell for barley yields on different soils. The soils occur under not very dissimilar climates and complete manuring was given, so the results are presumably due to the effect of soil type. For a loamy soil on an Old Red Sandstone drift the average yield over ten years was 40 cwt. per acre with the best 44½ cwt. Not far away a soil formed from purely carboniferous drift, but also a loam, gave only 30 cwt., with the best 30½ cwt. Over clay with flints, the heavy loam gave an average of 19 cwt. with the highest at 25 cwt., while a sandy loam over Lower Greensand gave an average of 18 cwt., the highest yield in the ten years being 29 cwt.

The soil on the Old Red Sandstone drift is a mellow loam with an excellent structure down to about 3 feet in some cases, with particles of lime scattered through the whole depth. The soil on the purely carboniferous drift, while still loamy in the surface layer, has a tight, compact subsoil which is prone to waterlogging.

From these examples the point that I made earlier can be understood—that comparison of the influence of texture itself on fertility or productivity is more or less impossible because of the changes in other factors that accompany changes in texture.

Extensive use of soil survey methods has been made in connection with fruit growing in certain parts of the country, notably in the Reading, Bristol and Wye provinces. It has been shown that there is quite a distinct correlation between soil series and fruit crop, other conditions being equal, and the soil maps have proved of great value in assisting in choice of sites and studying failures.

Since modern field experiments are expensive to carry out, it is desirable to have some method of correlating the data and extending their usefulness. There is little doubt that the soil map forms the best basis for this work. One can go further and quote in this connection the Director of the U.S. Soil Survey: "The entire agricultural enterprise is intimately related to the nature of the soil, and so an accurate soil map, together with its accompanying report, must be considered a handbook of the agricultural geography of an area." But the map and its report would also have their value for other purposes; few human activities are so remotely connected with the land that the soil and its utilisation can be completely ignored.

SOIL ORGANIC MATTER AND COMPOSTS

by
C. BOULD, M.Sc., Ph.D.
(Long Ashton Research Station, Bristol)

BEFORE the advent of mechanised farming, farmyard manure was regarded as the main source of supply of organic matter for arable land. However, with decreasing supplies of farmyard manure and increasing areas of arable land other sources have had to be explored. It is not proposed to deal with all of them, but to describe and comment upon some of the more important. They are: sewage sludges; crops as green manures; composts, including those prepared from town refuse or from straw treated with sewage sludge.

Sources of Soil Organic Matter

Sewage Sludges.—In order to obtain the best results from sewage sludges it is necessary to have some knowledge of the various types produced in this country. The main types are classified below, although modifications and mixtures are sometimes available.

Anaerobic.—(*a*) Raw primary sedimentation sludge.
(*b*) Digested sludge < tank digested. / shed dried.

Aerobic.—Activated sludge.

The crude sewage from the mains first passes through grids to remove large particles of organic matter. (This material is known as 'screenings'.) The sewage then passes over detritus traps (to remove grit) into sedimentation tanks. Here some fermentation takes place and much of the solid matter falls to the bottom of the tank and is drawn off at intervals. This is known as 'primary sedimentation sludge' and usually contains from 5% to 7% total solids. The effluent may be subject to secondary sedimentation, or pass direct to percolating filters for further purification before passing into streams or rivers. The raw 'primary sedimentation sludge' may be run directly into shallow lagoons where the surplus water is removed by drainage and evaporation. The length of time the sludge is allowed to remain in the lagoons affects its nature and composition. The raw primary sedimentation sludge contains a considerable amount of ether-soluble fatty material which makes the partially drained sludge difficult to handle and incorporate in the soil. Experiments carried out by the author showed that the readily available nitrogen in this type of sludge was nil, and when mixed with soil it immobilised nitrogen. After removal of the fatty material by extraction with ether, approximately 13% of the total nitrogen became available when mixed with soil.

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Sometimes the raw sedimentation sludge is digested, either in deep open tanks, or in enclosed tanks subject to temperature control. During the process the fatty materials are broken down, and the nitrogen becomes more available. The sludge is easier to dry and handle, and is sold as 'digested sludge'.

At some sewage works the primary sedimentation sludge is removed from the lagoons as soon as it becomes spadeable, and is stacked in heaps under cover. Fermentation sets in, the temperature rises, and the sludge dries out to a crumbly powder. This is sold as 'shed dried sludge'.

These three types of sludge—primary, digested and shed dried—contain from 3% to 4% of total nitrogen on a dry matter basis, of which not more than about 20% becomes available during the first year after application to the soil.

The total P_2O_5 content varies from 2% to 3% on a dry matter basis, and its availability may vary from nil to 50%. It is greater as a rule in domestic sludges than in sludges containing industrial waste.

The potash content of all sludges is negligible, the greater percentage being lost in the effluent.

A very different type of sludge is produced under aerobic conditions, and is known as 'activated sludge'. During this process more nitrogen and phosphate is removed from the sewage. On a dry matter basis this type of sludge contains from 5% to 6% of nitrogen and 3% to 4% of total P_2O_5. The availability of both nitrogen and phosphate is greater than in the anaerobic sludges.

Experiments carried out at Rothamsted have shown that sewage sludges must be regarded primarily as a source of nitrogen, and in some cases of phosphate. When potash is given in addition to sludge the response may be as good, for some crops, as with farmyard manure.

It is wise to avoid using sludge when it is known that it is contaminated with certain industrial wastes, particularly waste containing chromium, zinc, copper and other metals likely to be toxic to plant growth.

Green Manuring and Cover Crops.—Green manuring serves two main functions. The crop absorbs nitrates and other nutrients from the soil, when it would otherwise be fallow, and so prevents their loss by leaching; and secondly, if ploughed in at the right stage of development the organic status of the soil is maintained and sometimes increased. Very variable results have been obtained in the past due to an incomplete understanding of the changes in composition of the crop with age, and of the decomposition processes which take place in the soil. A brief account of these changes will help in understanding the principles of 'green manuring' (or composting within the soil) and composting.

When the plant is very young it consists largely of proteins and carbohydrates. After a certain stage in development the nitrogen content decreases and the percentage of fibrous material increases; in other words the carbon/nitrogen ratio increases with age. Generally speaking, when plant material with a carbon/nitrogen ratio greater than 20:1 is

incorporated with soil, the micro-organisms which decompose it will need more nitrogen than the plant material contains, and will obtain this extra nitrogen from the soil solution. In composting, therefore, one aims at reducing the carbon/nitrogen ratio until the product no longer immobilises nitrogen when added to the soil.

In green manuring, if the crop is ploughed in when quite young, it is readily attacked by micro-organisms, and rapid nitrification takes place. Some fleeting improvement in the soil structure may take place, and the final contribution to the organic matter status of the soil is low because of the low content of lignin and other fibrous material. On the other hand, if the crop is allowed to develop, or reach maturity, the carbon/nitrogen ratio of the plant will be high and when ploughed in some nitrogen immobilisation takes place, and unless a dressing of some nitrogenous fertiliser is given the following crop will suffer from nitrogen starvation.

The green crop should not be ploughed in when the soil is dry, otherwise decomposition will be delayed and the following crop may suffer from drought conditions, as a result of the competition for moisture.

The importance of maintaining the organic matter status in orchards is recognised. This can be achieved by the use of suitable cover crops, either annual or perennial. Research work is now in progress at Long Ashton to investigate the best methods and crops to use, and to study the effect of the various cover crops on the soil structure, the penetration and availability of the nutrients in the soil, and on the general nutrition of the tree. It is too early yet to comment on this work.

Composts.—The subject of composts and composting has resulted in much controversy and statements bearing no relation to experimental fact. Composting is as old as agriculture itself, and has been practised in China for many centuries. The methods employed in China are empirical. The organic waste is mixed with earth, wood ash, and sometimes urine, watered and turned at intervals until the organic matter is reduced to a dark brown fibrous mass. Labour is cheap and land is valuable, therefore maximum yields are essential. It does not follow, however, that similar practices are economical in this country where labour is more expensive.

Only since the advent of microbiology and biochemistry have the processes taking place in the compost heap begun to be understood. It is now known that micro-organisms are responsible for the decomposition, and that certain plant constituents are more readily attacked than others. During the process the carbon/nitrogen ratio is lowered and there is a considerable loss of organic matter and frequently of nitrogen.

For optimum rate of decomposition it is necessary to make available for the micro-organisms an adequate supply of nitrogen, phosphorus and water, and to prevent the reaction from becoming too acid. It is usual to maintain aerobic conditions for the initial phase, so as to avoid smell nuisance, but the secondary decomposition may be anaerobic so as to avoid losses of organic matter and nitrogen.

During the war years, research work was carried out by the writer at Reading on the preparation and investigation of composts prepared from town refuse and straw treated with sewage sludge. Some of the practical aspects of this work are described below.

Experiments with Sewage Sludge Composts

Refuse-Sludge Composts.—One of the largest potential sources of organic matter is town refuse. From time to time attempts have been made to use it for agricultural purposes, either in its undecomposed state or after fermentation. It is estimated that about 8½ million tons of dry household refuse are produced annually in England and Wales. About 2 million tons of this consists of organic matter.

Some of the sewage, both domestic and industrial, is not treated for the separation of sludge, but it is estimated that the available sludge amounts to about a half-million tons of dry matter per annum.

If these two sources—refuse and sludge—could be combined and composted, it is estimated that about 3 million to 4 million tons (fresh weight) of mature compost could be produced annually. It would be necessary, however, to erect salvage plants on or near the sewage works for the separation of organic matter from the refuse. In the space available it is possible to give only a summary of the experimental work.

(1) Adequate attention must be given to the preparation of a refuse rich in organic matter, by screening and salvage. The refuse should be pulverised prior to composting.

(2) Specially constructed cells, provided with aeration channels should be used for the initial composting period.

(3) Control should be exercised over the proportions of liquid sludge and refuse used. Normally the refuse will not absorb much more than its own weight of liquid sludge containing 5% total solids. The refuse and sludge should be intimately mixed prior to treatment in the aeration cells.

(4) It is not necessary to add nitrogen, phosphorus or calcium carbonate.

(5) The aerobic phase should not exceed a fortnight otherwise excessive losses of nitrogen and organic matter occur. There is some evidence to show that if activated sludge is used the losses of nitrogen are reduced.

(6) The compost should be stored until tests indicate that it is mature. Chemical and biological methods have been evolved for this purpose.

(7) It was found that during the initial aerobic phase ammonification of the nitrogen compounds was very rapid, and at the end of a fortnight from 20% to 30% of the total nitrogen was present in the form of ammonia. For this reason it is not advisable to prolong the aerobic phase, because the high temperature (60°C. to 70°C.) and alkaline conditions result in heavy losses of nitrogen.

(8) The availability of the nitrogen in the mature compost varies from 10% to 15% during the first season. The phosphate availability is also low.

(9) In certain composts the zinc content was sufficiently high to cause temporary depression in plant growth when used in pot experiments.

It will be realised that to prepare refuse-sludge composts on a large scale, and of sufficiently high organic content to warrant its use as a manure, special plant is required. Without attention to the separation of organic matter from mineral matter, and control over the decomposition phases, only a second-rate product can be obtained.

Straw-Sludge Composts.—About 1920 it was shown by Hutchinson and Richards that in order to decompose straw it was necessary to add nitrogen, phosphate and a base to keep the medium neutral. They found that 100 parts of dry straw required from 0·7 to 0·75 parts of nitrogen for optimum decomposition.

Because of the shortage of artificial fertilisers during the war, an investigation of the use of sewage sludge for composting straw was proposed. Experiments were carried out both in concrete cells provided with under-aeration, and in open heaps. It was found that there was less waste when cells were used, but composts could be prepared in open heaps using a simple technique. Both liquid and drained sludge were used.

Compost Making

Technique.—When building a compost heap on a large scale it is better to build it in sections, completing each section in a few days, otherwise the heap may become sealed and remain cold. This necessitates remaking. The technique for making a compost heap with liquid sludge is as follows. Prepare a well-drained site to take away seepage. Mark out the size of the heap, which can be of any length but should not exceed about 5 yards in width. At intervals of about a yard lay down lines of 6-in. unglazed drain pipes running across the heap. Duck boards have also been used successfully. The pipes should extend a little beyond the outsides of the heap. A layer of straw about 9 in. to 12 in. thick is then put in place and thoroughly wetted with liquid sludge. The process is continued until the heap is from 5 to 6 feet high. If properly constructed, without undue consolidation, the temperature should begin to rise in a few days and reach a peak about the seventh to tenth day. Internal temperatures of from 60°C. to 70°C. may be reached. The temperature will persist for a few days and gradually fall. If the heap is constructed during the summer months a second sludging, or watering, will be necessary after about three weeks. On no account must the heap be allowed to dry out otherwise decomposition will stop. The compost should be ready for use in 6 to 9 months.

The technique for the construction of the heap using drained sludge is similar, except that each double layer is wetted with water or effluent.

It is most important that the layers of sludge should not be too thick, nothing more than a sprinkling, otherwise aeration is impeded. Turning is not necessary unless the heap fails to heat. The outer layers will naturally dry out, and should be removed and incorporated in the next heap.

When drained sludge was used on a 1 : 1 dry matter basis of sludge to straw, the compost took six months to mature. When the ratio was 2:1 the period was reduced to about three months.

It was found that the availability of nitrogen in mature straw-sludge compost varied from 10% to 20%. The sludging of straw is not accompanied by such liberation of ammonia as with refuse compost, and the losses of nitrogen during decomposition are not so great.

Pros and Cons of Composting.—In favour of composting it can be said that the high temperature produced in properly constructed heaps tends to destroy weed seed and pathogens. The physical condition of the material is also improved. After composting it is less likely to immobilise soil nitrogen. In fact it is a safer product. On the other hand losses of organic matter and nitrogen may amount to as much as 40% to 50% during the process of decomposition. The availability of nitrogen in the secondary compounds is usually very low. It is also known that decomposition of organic matter within the soil has the greatest effect on soil structure.

An interesting experiment was carried out, in conjunction with a pot experiment, to compare composts prepared from sludge and straw under controlled laboratory conditions, with equivalent amounts of straw and sludge allowed to decompose in the soil prior to planting. The proportions of sludge and straw were so arranged that no immobilisation of soil nitrogen would occur. It was found that nine weeks' decomposition *within* the soil was equally effective on the growth and yield of spinach beet as nine weeks' decomposition under controlled laboratory conditions. Decomposition outside the soil resulted in a loss of 23% of organic matter and 12% of nitrogen.

Rothamsted experiments have shown that when straw and ammonium sulphate were added separately to a potato crop, the yield was greater than when the ingredients were composted prior to use. More information is required, but it does appear that the value of a compost as a fertiliser is no greater than the ingredients used in its preparation. Attention has also been drawn to the low availability of nitrogen in composts. For certain crops, composts used at average rates do not provide sufficient nitrogen for optimum growth. The best results are almost always obtained when nitrogen is used in addition to composts. In fact composts should be regarded primarily as a source of organic matter. When used under normal fertile soil conditions they begin to lose some of the 'halo' with which some advocates have surrounded them.

RECENT WORK WITH SEED AND POTTING COMPOSTS

by
W. J. C. LAWRENCE
(John Innes Horticultural Institution, London, S.W.19)

In a recent world survey the Food and Agriculture Organisation found that one in two people was undernourished and one in six was at a marginal level. These are startling figures, food conscious though we are in Britain.

When we turn from people to plants, the figures are even more startling. Worse still, growers are quite unconscious of the extent and degree to which undernourishment pervades their crops. I estimate that not one in thirty commercially raised pot plants has an adequate diet. Most plants are undernourished and many suffer starvation.

To some readers these statements about the nutrition of glasshouse crops may seem so sweeping as to be unacceptable. Well, the way out from this mental dilemma is simple. Any competent person can, with proper guidance, make comparisons between the new and old methods, and prove for himself the truth of the matter.

Meanwhile, the purpose of this account is to present a few of the facts ascertained at Merton about pot plant cultivation, and to arouse in horticulturists the need for securing full nutrition, and thereby better crops, under glass.

Pot Plants Undernourished

How prevalent is undernourishment in pot plants? An answer to this question can now be given. Here are the facts. In response to requests from Merton, fifteen growers each sent a bushel or two of the compost they normally used for raising tomatoes in 60s. Nine of these growers had nurseries in Surrey, four in Middlesex and two in Buckinghamshire, so we may assume that the fifteen composts were representative of those used in the south of England, if not in the whole country. The loams employed varied from light sandy to heavy clay. Sterilised loam was used in five composts, unsterilised in eight, and a mixture of sterilised and unsterilised in two composts. In six cases, animal manure had been employed, in five cases peat and in two cases leafmould. Sand was rarely used and only one had a sufficiency of coarse sand. These variations in the choice of materials are, of course, typical of commercial practice.

Two tests were made with tomato Potentate, using the John Innes composts for comparison; one test in the period of January to March, the other April to May. Thus the behaviour of the plants was observed under

This paper was read at the Revision Course in September 1946 and deals with developments up to that time.

both indifferent and good light conditions. When the plants arrived at planting-out size (3½-in. pots), they were scored for weight, height, size of flower truss and for foliar characteristics.

The results were striking:

1. Growth in the different composts was extremely variable.
2. Only one compost was as good as the John Innes Potting compost.
3. Only four composts were as good as the John Innes Seed compost.

To put this in plain English, only one in fifteen plants was properly nourished: the rest were suffering from undernourishment or starvation.

Since all the fifteen growers were reckoned by their county horticultural officers to be equal to or above average in their standard of cultivation, we are forced to the conclusion that the great majority of commercial pot and box plants are undernourished.

John Innes Composts

The evidence does not end there. For three years I have been carrying out intensive investigations on the cultivation of plants under glass, and now possess an abundance of experimental evidence on all the fundamentals of the subject. The results are as striking as those obtained with the growers' composts. They round off the picture, and the argument. I can only give a few examples here: the full account has been published elsewhere.[1]

Tomato

(i) M.P. was raised in 3½-in. pots in (1) J.I.S.,[2] (2) J.I.P.1 and planted out under glass in the usual manner. In the first week of fruiting 72% more fruits were picked from the plants raised in J.I.P.1 as compared with J.I.S.; 59% in the first two weeks; 35% in the first three weeks and 20% more in the first month.

(ii) Potentate was raised in 3½-in. pots in J.I.S., J.I.P.1 and J.I.P.2 and planted out of doors. J.I.P.1 gave 53% and 33% more fruits than J.I.S. in the first two and three weeks of picking respectively, while J.I.P.2 similarly gave 42% and 17% more fruit than J.I.P.1.

It will be seen from these figures that large increases in the early yield of tomatoes can be achieved by using the right compost. When it is remembered that ten of the growers' composts failed to come up to J.I.S.

[1] *Science and the Glasshouse.* Oliver & Boyd, Edinburgh.

[2] J.I.S.=John Innes Seed Compost. J.I.P.1=John Innes Potting Compost to which one dose of base fertiliser and chalk is added. J.I.P.2=John Innes Potting Compost to which two doses of base fertiliser and chalk have been added, and so on.

The formulae of John Innes Composts are as follows:

Seed compost: 2 parts sterilised medium loam, 1 part moss—or sedge—peat, 1 part coarse sand plus 1½ oz. superphosphate (18%) and ¾ oz. ground chalk per bushel.

Potting compost: 7 parts sterilised medium loam, 3 parts moss—or sedge—peat, 2 parts coarse sand plus 1½ oz. ⅛ in. grist hoof and horn (13% N), 1½ oz. superphosphate (18%), ¾ oz. sulphate of potash (48% K_2O) and ¾ oz. ground chalk per bushel.

standard, it will not be difficult for readers to form an opinion as to the preventable loss in early yield which occurs in the glasshouse industry.

Lettuce

(i) W. and S. No. 2 was raised in boxes using J.I.S., J.I.P.1 and J.I.P.2, and planted out of doors in April. With J.I.S., 57% of the total crop was cut at the first cutting; 83% with J.I.P.1; and 91% with J.I.P.2. The quality of the plants was proportionate to these figures.

(ii) Cheshunt Early Giant, Early French Frame and Gotte à Forcer were raised in boxes in J.I.S. and J.I.P.1 and planted out under glass in September. J.I.P.1 gave a 22% heavier crop than J.I.S.

Lettuce growers will know that a crop which comes in a few days earlier than the average may make all the difference to returns. The improvement in quality which goes with using the right compost should not be overlooked.

Cauliflower

Forerunner, sown in January in a cool house, was raised in 3-in. pots in J.I.S., J.I.P.1, J.I.P.2 and J.I.P.3 and planted out of doors in April. During the first week of cutting, J.I.P.1 gave 100% more plants than J.I.S.; J.I.P.2 370% and J.I.P.3 380% more.

Flowering Plants

It should be noticed that the above examples refer to plants which remain in pots or boxes for a short time only before they are planted out in their permanent quarters. In cases where the plant remains in a pot for the whole of its life, the improvements obtained by using the John Innes composts are still more marked (see below).

Thus, *Primula malacoides*, *P. obconica* and *P. sinensis*, Cyclamen, *Solanum capsicastrum*, Chrysanthemum, etc., all grow very much better in the John Innes composts than in those used and recommended by growers. Moreover, crops mature in 20% to 30% less time with a corresponding saving of space in glasshouses and frames. Lower temperatures can be used and resistance to disease is often greater.

Faulty Composts

At this stage we may ask, "What are the faults of the old composts?" First, and above all, there is nutrient deficiency. Soil conditions in a pot are highly artificial: there is little soil and the roots of the plant cannot go foraging. They must live on what is in the pot. When traditional materials are used to make the compost it is soon exhausted of one nutrient or another. Hence the greatest single improvement that can be made in pot plant cultivation is the addition of a suitable base fertiliser to the compost.

A concentrated supply of nutrients, however, is not the complete solution to the problem in plants any more than it is with man. For

example, a satisfactory diet for humans must include roughage to ensure good bowels action. So too, in plants, 'roughage' must be added to the compost to ensure good root action. In other words, suitable organic material such as peat, together with some coarse sand *must* be incorporated. The great majority of growers are unaware of this or ignore it and use composts of poor texture.

Peat, incidentally, must not be regarded as merely aerating the soil. It has two other valuable functions. It regulates the water supply and reduces the loss of nutrients caused by leaching. Leaching not only wastes nutrients: it leads to nutrient unbalance as a consequence of some nutrients being more easily washed out than others.

Lastly, soil sterilisation is usually neglected in the old composts with the result that many plants are lost from the attacks of peats and diseases: and nutrients which the sterilising process makes available to plants are not utilised as they might be.

These faults of nutritional deficiency and unbalance, of poor texture and unhygienic materials, are entirely preventable. Yet most growers accept them, without a thought, as inevitable. It is time that we realised that all these troubles are symptoms of unscientific and out-of-date growing. We need to become acutely aware of this truth.

Undernourishment and unhealthiness disappear with the John Innes composts, which cost only a little more than the old composts to prepare. I would particularly draw attention to the following figures. If high-pressure steaming is used, the *extra* working costs of preparing John Innes composts, including labour, fuel and fertilisers, is estimated at 5*s*. a cubic yard or about 1*d*. for thirty-three 3½-in. pots. With low-pressure steaming, the figures are 7*s*. a cubic yard and 1*d*. for twenty-five pots. Even if for some reason or other the costs on a nursery were two or three times as high as those mentioned here, the extra expenditure is negligible.

Standard Composts

So much for costs. There is another point, far from being properly appreciated by growers, which needs emphasising. It is that the man who uses the John Innes composts is using precision tools. Unfortunately, the horticulturist, unlike the engineer, not only has to use these tools, but he has to make them. If the formula says 'hoof and horn', bonemeal, tankage or soot are *not* 'just as good'. This frame of mind, that something else will do if you haven't got the right thing, betrays a failure to appreciate the principles of good growing. Precision tools must be precisely made from precise materials. This is the only way of guaranteeing consistently good results.

The merit of the John Innes composts is that they are *standard* composts and will give the same good results again and again—*but only if standard ingredients are used.* This presents no difficulties where the fertilisers, sand and peat are concerned. So long as the sand is clean and

PLATE I (C. E. ELMS)

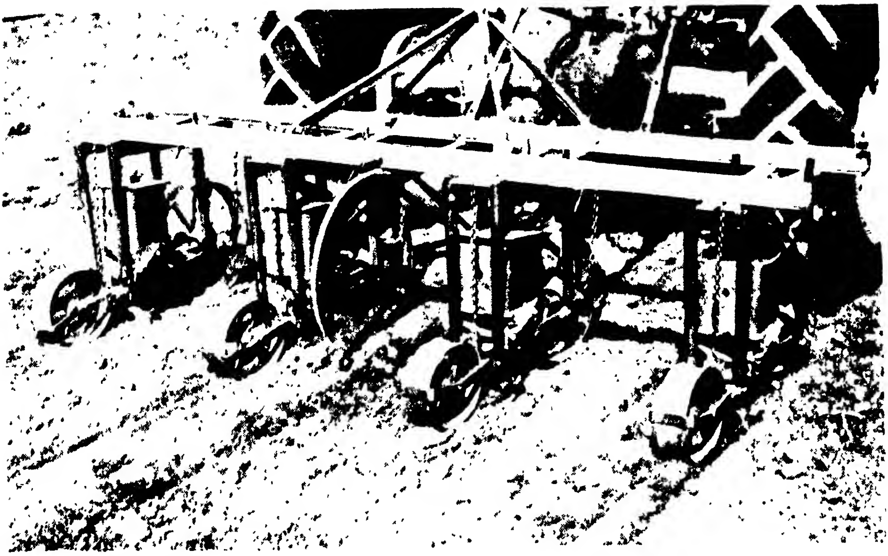
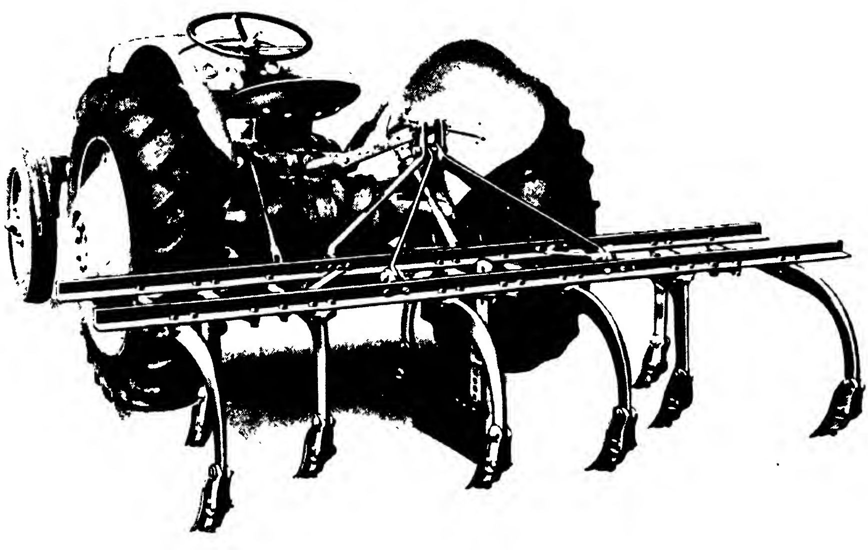


FIG. 1. DRILLING WITH UNIT SEEDERS ON REAR TOOL-BAR
Drill width can easily be varied



(By courtesy of Harry Ferguson Ltd., Coventry)

FIG. 2. SELF-LIFT UNIT PRINCIPLE
Enables headlands and corners to be thoroughly worked

PLATE II (C. E. ELMS)

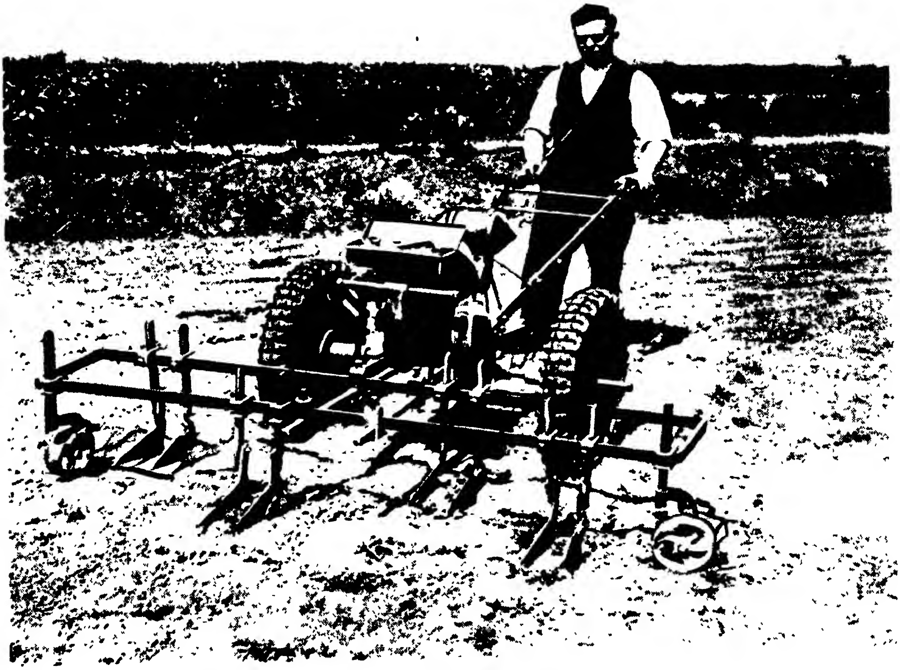
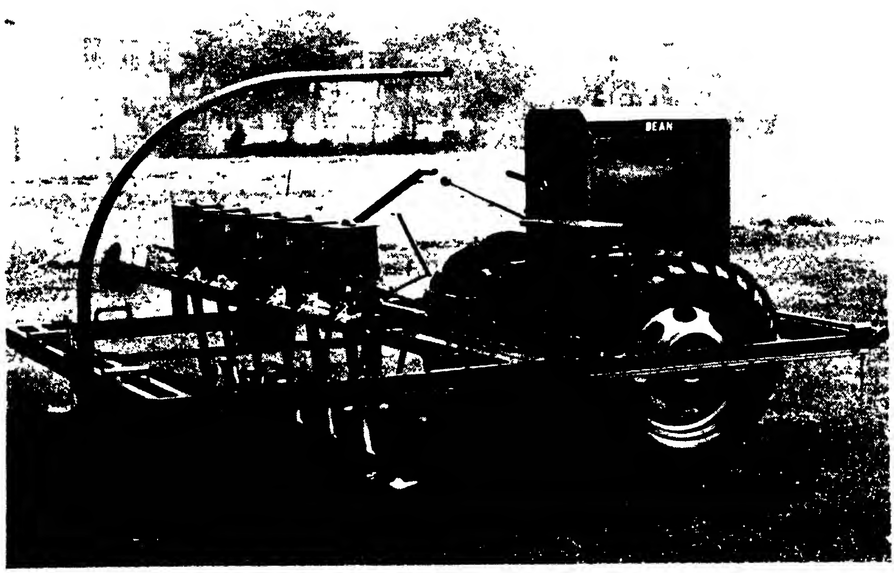


Fig. 3. A Light Hoe on Front Tool-bar
Ensures accuracy of work and easy steering



(By courtesy of Humberside Agricultural Products Co. Ltd., Brough)
Fig. 4. A Modern Forward Tool-bar Chassis
Allows rapid change of matched tool sets

coarse, the peat of good texture, and the hoof and horn the right grade ($<\frac{1}{8}$-in. grist), little can go wrong with these ingredients. I know of no case where peat, sand or fertiliser, as specified, have been responsible for indifferent results.

Importance of Loam

Loam is on a different footing. It is the most important ingredient and the least standardised. The less suitable loams are indicated in John Innes Leaflet No. 6. The ideal material is the top spit from a first-class pasture on medium loam soil, cut in early summer for use the following spring. Turves and soil from such a pasture will supply humus in exactly the right forms, have a good calcium and phosphorus status, and be what I call biologically fertile. Fertile arable soil *of good texture* also ranks high, so long as it is not lighter than a medium loam. The point I wish to emphasise is that to get the best results loam, whatever its source, should be in good heart *before* it is stacked. It is not easy to create the right conditions afterwards. Good loam, however, is exceedingly scarce just now, and most of us have to make do with inferior material. How should this be treated?

First, it should be realised that although sterilisation and the use of fertilisers can greatly improve bad loams, no amount of this fortifying will make a bad loam give good results. Therefore, the first thing is to choose the best loam available. It if comes from a poor pasture, it will probably be deficient in phosphorus and calcium and biologically infertile. The only thing that can be done to improve such a loam is to compost it. By that, I mean stack the turves with some old manure, composted straw or fertile arable soil between each layer, applying appropriate dressings of superphosphate and calcium carbonate to alternate layers. This composting should be done carefully. The turves should be moist to the point of wetness, stacked loosely and watered if a period of drought sets in during the following four months. A similar procedure should be followed with soil from second-rate arable land.

To sum up, a suitable loam for pot work should have a good crumb structure, contain a moderate amount of clay and humus and an adequate content of available phosphorus, and have had its pH adjusted to 6·3. The aim of composting an inferior loam should be to build it up to these standards.

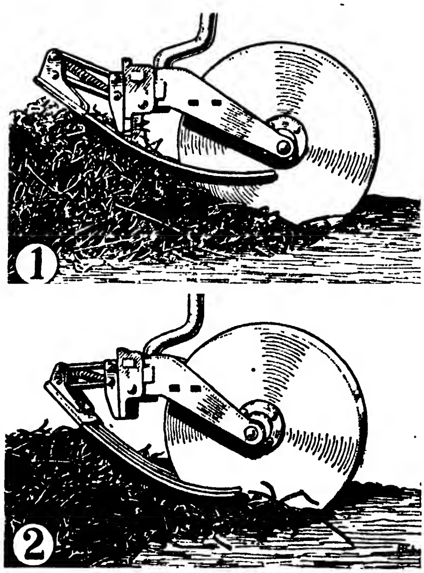
Routine Practices

Growers who change over to the new composts will find that they must make one or two alterations in their routine practices. Failure to appreciate this has occasionally led to expressions of dissatisfaction. For example, the vigorous growth in John Innes composts may become soft growth if the same temperature and humidity are followed as before. Coddling plants is a practice of the past no longer necessary or desirable.

Re-timing of all crops is essential since growth is so speedy. This rapid growth also means that the man who feeds by the calendar and not by the plant's requirements may get caught out. Watering requirements, too, are sometimes different. However, once these new adaptations are understood, they become mere routine and no more bother than before.

Apart from the better growth obtained with the John Innes composts, there is another distinct advantage. The composts allow much greater latitude in methods of raising plants. What is difficult with the old style of compost becomes not only easy with the new, but desirable. For example, the number of potting shifts can be cut down, with a saving in labour. Or, to quote a special case, seeds can be sown or seedlings pricked out in large pots in mid-winter without any fear of 'cold' effects from the large mass of soil. Also cucumbers can be grown under commercial conditions, but without using any animal manure.

Under the difficult conditions of the war years, British growers have done excellently in the raising of food crops for the nation. There is no reason why, under the easier conditions of peace, they should not do equally well in raising their standards of cultivation, with benefit to both the horticultural industry and the nation. Two things only are necessary to achieve this. Growers must become *aware* of the possibility, and know the means of achieving it.



TEXT FIG. 1.—THE SPRING LOADED GUARD

RECENT DEVELOPMENTS IN HORTICULTURAL MACHINERY

by

C. E. ELMS, B.Sc., N.D.A.(Hons.)

(The University, Reading)

DURING the last war this country progressed in food production to such an extent that it is now perhaps the most highly mechanised in Europe in this respect. Machinery had to make good the shortage of labour, and not only has there been a great increase in the number of those types of machines and implements that existed before the war, but the war years themselves witnessed improvements and new ideas, all designed to make the man-hour more productive.

Since the war we have noticed that a number of firms, hitherto employed on armament production, have turned their attention to operations on the land. No doubt these people will attempt to apply the lessons they learned in respect of materials and their fabrication. Many of these manufacturers will view the various problems purely from the engineer's viewpoint, and, unless they seek advice from those connected with the land, it is more than likely that many of their productions which are solutions on the drawing-board, will be failures in practice.

We appear to be in for some startlingly new ideas. Very recently a two-wheeled tractor was demonstrated working under remote wireless control, and I was told by someone privileged to watch the demonstration that it was an efficient unit. It is apparently quite simple to combine with the unit a television set, which would enable the operator to remain at home and assist with the peeling of the potatoes.

Soil Preparation

As the plough is the basis of soil preparation, I shall deal with it at the outset of a consideration of the more recent developments in implements and machines. There has been no change in fundamental design, but a new form of rolling coulter has been evolved by the N.I.A.E. which gets over the difficulty experienced when ploughing in a deep layer of trash or even long-strawed manure. The new coulter has a wavy edge, the result of deep corrugations running towards the centre. It has been severely tested and proved efficient. To deal with this same problem a recent American idea is to have a four-fingered guard ahead of the coulter. It is spring loaded in order to press the material close to the ground (see Text Fig. 1, opposite).

It may perhaps not be out of place to mention that in many cases the

This paper was read at the Revision Course in September 1946 and deals with developments up to that time.

failure of a coulter to make a clean cut is due to a blunt edge, which may be the result of neglect in lubrication.

To speed up the break-down of the furrow one firm has designed short knives in the shape of shark fins. These are attached to the tails of the breasts, and pulverise the overturned furrows.

Perhaps the most interesting search at the moment is for a multi-bodied one-way plough. Ploughing with standard ploughs results in a number of open furrows that are a nuisance when mechanical hoeing is practised. Single- and two-bodied one-way ploughs have been in existence for a long time past, but where powerful tractors are available to the larger growers both time and labour could be saved by an implement with more bodies. A prototype of this kind was shown recently at a demonstration in Worcestershire. It carries two sets of four bodies, and it needs a powerful crawler and a big headland on which to turn.

Before passing to cultivating implements I should refer briefly to the question of deep ploughing. Repeated ploughing at the same depth often results in the formation of a plough-pan which may not only interfere with the movement of moisture but with the freedom of plant roots. Special deep-digging ploughs are available, but it is also possible to get the effect by replacing the leading body of a two-furrow general purpose plough by a sub-soiling line capable of penetrating deeply into the bottom of the open furrow.

There has been an interesting development at the N.I.A.E. with regard to deep ploughing by means of the larger-powered two-wheel tractors. It is, I think, generally agreed that ploughing at any depth with these machines is not always a satisfactory business. The new idea consists of mounting on the front of the tractor a cable winch chain driven through a reduction gearing by the tractor's engine. The land wheels are declutched. One end of the cable is attached to an anchor of a headland. The cable is paid out and the tractor starts from the opposite headland. As the winch winds the cable, the tractor is drawn along. A plough capable of deep work is attached to the tractor. At first considerable trouble was experienced in preventing the cable piling up at the centre of the winch drum.

The tractor used was a 6 h.p. model with a reverse gear, an important point. The average depth of ploughing was 11·9 inches and the width 13·8 inches. The pull on the cable averaged 1600 lb. In a stalling test a pull of 2400 lb. was reached. The average speed of the outfit was 3 to 4 miles per hour.

To pay out the cable the tractor runs back to the starting headland free, and this is where the reverse gear is important. The anchor is so designed that by pushing the clip holding the cable along it, seven 14-inch furrows can be ploughed before refixing is necessary.

The break-down of the soil after ploughing is done by tined cultivators, disc harrows or rotary cultivators. Tined cultivators continue to follow conventional patterns, with perhaps in some cases a tendency to increase

their strength and weight to get the deeper penetration possible with high-powered tractors.

The disc harrow has increased in popularity of recent years, and can be a good soil pulveriser. Although the depth of penetration is controlled by the angle at which the implement is worked, deep penetration can be obtained only by the heaviest types. It must be borne in mind that discs bring nothing to the surface, and thus have no cleaning effect; their sharp edges cut through roots and stolons, thus propagating twitch and docks, and their weight acts as a consolidator of the lower soil layers, a condition that may be an advantage or a disadvantage.

These implements are expensive, and unless the disc bearings are constantly lubricated they soon cut badly and there follows a costly repair bill; furthermore, when used on a gritty soil the discs wear rapidly and are not a cheap item to replace, as they are made of high carbon steel.

The final tilth is obtained by the use of harrows, and in some cases the roller may be useful. The controlling feature is the friability of the surface clods. Often light, straight-tined harrows prove very effective, and at the same time they pull trash to the surface. Many favour the use of the spring-tine harrow, especially where the clods are hard, maintaining that the vibration of the tines has a smashing effect.

An implement not much seen in this country but popular on the Continent in the sugar-beet areas is the planker or scrubber. This consists of a number of hard-wood planks nailed to two or three heavy battens, the long edge of one plank riding on the edge of its adjacent plank after the manner of weather boarding. The construction is then drawn over the ground with the proud edges of the planks passing over the clods. If necessary extra weight in the form of sacks of earth or heavy stones can be added. This implement, easily constructed at home, has a great pulverising effect.

When using the roller to get the tilth, discretion must be exercised. It can prove a boon, but it can be a real danger. Firstly, it must be realised that it will give consolidation, a desirable effect on puffy soil but a condition to be avoided on the heavier lands. Secondly, the clods may break too easily under the weight and give a very fine tilth; but with some soils this fine tilth runs into a cake with the first fall of rain, and then bakes into a solid crust. There are two main types of roller, the flat and the Cambridge or ring roller. The flat may be of stone, steel or wood, and some growers prefer the wooden roller. The Cambridge roller consists of a number of narrow independent V-shaped rings on a common shaft. These are perhaps the better clod crushers, and they leave the land in a close series of fine furrows. The lighter disc harrows are also quite useful as surface mulchers, and in addition have, as already stated, a consolidating effect.

Rotary Tillage

The foregoing picture of seed-bed preparation shows the use of three distinct classes of implements—the plough, the cultivator and the harrow,

with possible addition of the roller. However, there have been as far back as the middle of the last century people who have considered that the three distinct operations could be rolled into one by some form of direct mechanical tillage. The same idea persists today and the machines available fall into three classes.

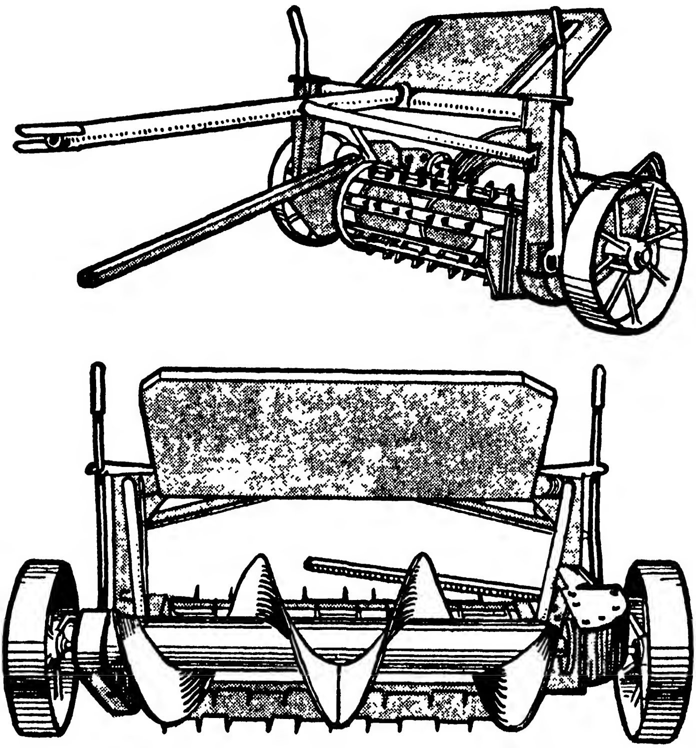
The massive gyrotiller stands alone in having its tines on vertical shafts, and as the machine travels forward these tines, mounted on two crown-wheels, stir the soil like an umbrella in a Christmas pudding. Some very remarkable effects have followed the use of this machine, but it is more than probable that the increased fertility was due to the deep 'ploughing' by the long tines. It is quite a useful weapon for grubbing up plantations of gooseberries or blackcurrants. In using this machine on land that is liable to 'poach' when wet, it is as well to make certain that the lower layers are dry, otherwise these may be so stirred as to cake hard on drying out. These machines are primarily contractors' equipment, they require great power—180 h.p. in the biggest models—and the tractor, usually a crawler, has to be very low-geared. It should perhaps be pointed out that these machines were designed originally for sugar-cane plantations abroad.

The second class of machines are designed to have their tines carried on a horizontal shaft. There are three or four examples, each requiring at least a medium-powered tractor with a power take-off shaft to drive the miller. As the machine is pulled along, the fast-moving tines cut into the soil and throw it up into the air. The third class of machines are designed on the same principle but are miniature in size. These are walking machines which are often powered by engines of only 3 h.p. Rotary tillage machines are again coming on to the market, in fact one firm has a matched combination of tractor and tiller. The tractor is interesting as it is a 25 h.p. Diesel crawler of very low clearance overhead and of very narrow width.

Anyone watching the work of these machines will, I think, be struck by one or two outstanding features. The whole of the disturbed soil is thrown into the air, stones and clods held together by plant roots come to rest on the surface; and the final tilth is very puffy. Moreover the tines if at all edged might cut weed stolons and increase an already dirty condition.

Some experiments have been carried out in the past to compare rotary tillage with conventional tillage, and the general conclusion would seem to be that germination was usually quicker and more uniform on the rotary tillage, but the weeds appeared to benefit even more. During later days of growth the initial advantage was usually lost; in fact the plants on the conventional tillage were ahead. It was considered that the falling off was the result of lack of consolidation due to the puffy state of the soil.

For the grower with small strips to cultivate, I do not think it would be out of place to recommend his using one of these miniature tillers if the land were reasonably clean from the previous crop. The application of a roller could give the necessary consolidation.



TEXT FIG. 2.—THE 'WILD' DUNG HEAP SCATTERER

Manure Distribution

The distribution of farmyard manure and artificial fertilisers is a problem that faces horticulturists and agriculturists alike. Taking firstly the case of farmyard manure—there are special trailers and waggons fitted at the rear with a mechanically operated scattering device. The loading of these, if done by hand forking, is an expensive item. Lately, however, there has been the development of mechanically operated grabs, buckets and forks to meet this requirement. Some of these can be fitted to tractors and are therefore mobile. They are suited to open yards, but where the manure is inside a shippen they are useless. These contrivances work best with well-rotted dung or where the bedding was of straw that had been well broken by a peg-drum thrasher. Considerable skill is needed when dropping the manure into the waggon to make an even load, or indeed, to prevent half of it falling over the sides.

There is certainly scope for a good deal of improvement in both loading and scattering devices on waggons. A very recent implement is one used to distribute small heaps of manure that have been dumped in the field. It consists of a fast-moving peg-drum feeding the manure to a broad-bladed auger. It is pulled and powered by a tractor and is driven straight over the heaps (see Text Fig. 2).

With regard to the spreading of artificials, there is need for machines

capable of carrying greater loads and spreading a greater width. At the moment only one box-type distributor capable of a 20-ft. spread is available. It is, of course, possible to gang three 8-ft. distributors by a special framework, but it is very difficult to adjust all three to work at the same rate. The most persistent attempts to solve the problem have been to attach a distributing mechanism to the tail of a lorry. One form is to have a wide trough with its ends projecting on either side of the lorry. A full load of fertiliser is carried in bags and a second man empties the bags into a hopper at floor-level. Conveyor belts or augers carry the material to the extremities of the trough, the release to the ground being through some adjustable gate mechanism in the bottom of the trough. A second form is for the hopper to feed the fertiliser on to a whirling turn-table. These have a very wide scatter—about 30 ft.—but the area cover is by no means uniform. With both designs the power needed is obtained by a chain drive from a sprocket fixed to one of the rear wheels of the lorry.

With regard to lime spreading, there has been an improvement. In many parts of the country it is now possible to be brought to the field in special lorries fitted at the rear with a distributing device. These are capable of spreading up to 3½ tons per acre.

Seed Drills and Transplanters

The establishment of the plant in the soil may be either by sowing seed or by transplanting seedlings. The direct seeding of plants can be done by drills, but this operation so far as horticulture is concerned is far from happy. The usual machines employed plant a continuous row which may be left as it is, but in horticulture, where single plants are more often required, the surplus plants have to be got rid of.

Until the advent of the tool-bar attachment to tractors, the horticulturist had to be content with single-row seeders unless he could make use of the drills provided for the farmer. There are now, however, unit seed drills that can be attached at will to tool-bars. This arrangement has one advantage, in that the drill spacing can be kept accurate for succeeding inter-row crop work (see Fig. 1).

A good deal of effort has been expended in attempts to design single-seed spacing drills that would obviate the costly process of singling, but up to the present designers have succeeded only in obtaining a bunching drill. This certainly does away with chopping out. Under test, this drill gave the best results with onion seed. It was also good with other seeds, but where the spacing was not good as with turnips and carrots it did give a fairly even drill. The result with peas was disappointing.

When the crop is to be established by transplanting seedlings, the placing may be by dibbling or by one of the mechanical transplanters. Apart from the labour saved and the speed of operation, two advantages are claimed for these machines—firstly, the wide furrow opened allows the roots of the seedling to fall into their natural position, and not be bent upwards as so often happens when they are dibbled. Secondly,

it is possible with some machines to carry a tank which delivers a quantity of water with each seedling. In addition, people of average intelligence can be quickly trained into efficient workers, whereas a rapid, skilful dibbler is not so easily found. The transplanter is now well known; it can deal with quite a wide variety of crops and its popularity is increasing.

Weed Control

As the grower is well aware, his biggest battle—that against weeds—now begins. Much work has been done, and indeed is still in progress, in order to find chemical dusts or sprays that will kill the weeds while sparing the plant. Some success has been achieved in this field, but until the chemists can provide protection for every crop the grower must still combat the weeds by hoeing.

With the coming of tractors it was no doubt confidently and justifiably hoped that both the backache and cost would be taken out of this operation. It is true that the steerage horse-hoe was a success, but the rate was slow and it required two operators. Similar but larger steerage hoes were made for use with tractors. Work was speeded up, but in place of the usual boy leading the horse we now have to employ a skilled tractor driver. Furthermore, the load imposed on the tractor is very light and it is extremely difficult to keep up the heat in the engine to a degree that will minimise crank-case dilution in tractors burning vaporising oil.

By mounting a tool-bar on the tractor itself the steerage man is dispensed with, but is the tool-bar a success in hoeing? Many will say "No". In fact I have met growers who have been 100% mechanised for a long time and are going back to hand push-hoes for such crops as peas. The trouble with the tool-bar is the constant wander from side to side. This may be very dangerous to the seedling, and if the side hoes are spaced too generously apart the weeds lying close to the plant will escape attention. On flat ground an even depth can be maintained; but where this is not the case, the rise or fall of the front wheels will cause the hoes to bite deeply into the ground or ride out of the work.

The positioning of the tool-bar on the tractor gives rise to argument. If it is attached at the rear, the tractor travels on firm ground and any wheel marks are removed. The driver is now faced with the difficult task of watching both his steering and the work of the hoes. If he corrects his steering a bit sharply, the tool-bar swings across the rows and whole lengths of plants can be wiped out. In addition a blocked pair of side hoes may wipe out seedlings before the driver notices the damage. Other positions for the tool-bar are ahead of the tractor or under the waist. With some outfits the positions are divided.

In many cases the fitting of tool-bars is a lengthy business, and the man who has only one tractor may not be able to confine its use for several days solely to the work of hoeing. In such circumstances the unit principle of implements, specially built for quick attachment, is a very great

advantage; but the tool-bar, like all the other implements, generally goes on at the rear (as shown in Fig. 2).

It is probably a well-appreciated fact that the power needed to pull or push a tool-bar fitted for hoeing is small, and this has led to the development of self-propelled frames. One which seems to be particularly useful has an 8-h.p. engine and can be used for several purposes. As far as I know it has not as yet been fitted for ploughing. It has a fairly wide range of implements that are mounted on a removable frame, and it is only a matter of a minute or so to change the tools (see Fig. 3).

A smaller type of the same sort has only a 3-h.p. engine, but its use is confined to hoeing and hand singling. For the latter purpose it can carry two operators seated in canvas slings that can be lowered to almost ground-level. A feature of this machine is the low gearing which permits a very slow rate of travel, thus giving the operators time to single by hand.

It must not be forgotten that small two-wheeled tractors can be used for hoeing. With some outfits the hoe bar is placed ahead, in which case wheel marks are not wiped out (see Fig. 4); but in some instances the bar is slung from the handles between the tractor and the operator.

The design of the L hoes working close to the plant is often criticised in so far that many of them do not leave the soil where it was. Some tend to push it away from the plant, but others tend to deflect it over the plants and so smother them. When discs are used there is no fear of smothering, but the plant is left on an embankment—which may or may not be a good thing.

For inter-plant hoeing there is now available a hand-operated machine capable of taking either two or three rows at a time. The hoe blades run between the plants and are opened by a foot-pedal to let a standing plant pass. The machine requires a minimum plant spacing of about 18 inches and a minimum width between rows of 26 inches. If the spacing is less than 26 inches, work can be done on two alternate rows at a time. The working rate is about 1¼ miles per hour, giving a rate of work per man four times that of hand hoeing. The tines cannot, however, be worked as close up to the plant as by hand hoes, but the machine does keep the soil up to the plant.

Potato Planting and Lifting

The potato crop has been left for separate consideration. It has certainly been the subject of much attention by engineers, and as yet one or two problems still await a real solution.

Planting of tubers by hand is still done by many growers, and if an experienced man can plant half an acre a day labour demand is not excessive. Mechanisation, however, does give a saving and is a good alternative where labour is hard to obtain.

There are available a very large number of planters capable of planting 1, 2 or 3 rows at a time. Some of them are able to deal with sprouted sets. Original designs were fully mechanised machines, but the trend of

late years has been to employ hand labour to fill the cups, belts or trays. The difficulty with the original cup type of self-feeding machine was that any particular size of cup was unable to deal with a sample of seed that varied in size and shape, and they certainly were of no use with chitted seed. Where the crop is to be treated mechanically in the after cultivations a 3-row planter is almost essential, such as that shown in Fig. 5.

The accuracy of spacing is often not all that could be desired; many or indeed most of the machines take their drive from the land wheels, and if there is heavy wheel-slip spacing suffers. Also potatoes do not always take the central line down the delivery chute. In fact one must be prepared to put up with an out-of-position drop of as much as four inches.

With many machines are incorporated fertiliser distributors which in the British patterns make no attempt to precise placing, and in addition the rate of feed by each element is not uniform. These machines are fairly costly and can be given a life of about five years. Thus, if a machine costs £100 and it does not produce a saving in labour of more than 10/- per acre, it is not economical on less than 40 acres.

With regard to the harvesting of the crop both the spinner and the elevator are no doubt well known. Most of these machines lift only one row at a time. It is possible to get elevators that deal with two rows, but considerable power is needed to operate them (see Fig. 6).

A recent development with regard to the elevator is the deflector. This is a fan-shaped screen of vibrating steel fingers attached at the back, and as the potatoes fall off they are deflected to the off side, thus leaving the land clear for the return bout and enabling the machine to be worked regardless of the rate of picking. A small 'plough' is attached to the off wheel to smooth out the rut, otherwise potatoes fall into this, making subsequent picking irksome.

A very recent introduction to assist in collecting potato crops is a large, slowly revolving cage-wheel, running alongside the crop row. Facing the cage, but sitting on the other side of the row, are two pickers. The platform on which they sit is almost at ground-level. Bending forward they pick the crop and throw it into the cage-wheel. The potatoes are carried upward by the wheel to drop on to a chute, which can feed bags or a lorry. Very slow forward speed is necessary.

After the potatoes have been elevated, some growers consider it foolish to drop them back to the ground. To carry them to a bagging device would be a simple matter, but along with the potatoes would be carried clods of hard earth and stones. In an attempt to deal with this problem the crop was carried on a horizontal conveyor with men on seats picking out the foreign matter, the potatoes being bagged at the end of the conveyor. This arrangement, however, does not seem to have made much headway.

About 1942, an interesting attempt at the mechanical separation of stones was made and a prototype of the machine built. It was powered by its own 2-h.p. motor, but it depended on a tractor for haulage. Every working part is rotary. Haulms are whipped off by a steel-tipped flapper

revolving at 600 revolutions per minute. The ridge and potatoes are then lifted bodily into a rotating riddle 30 in. in diameter by 24 in. long, containing curved helical strips. Clods are broken up and all the soil is flung out through the riddle, which is kept clean against a bristle brush. The potatoes pass into a large, cupped cage-wheel that lies in a plane at right angles to the line of travel. Any further soil is lost here, and the potatoes are carried upwards to drop on to a wide, flat chute. Half-way down this chute the bottom is replaced by the tips of a wide, rotating, cylindrical bristle brush. Stones lodge between the bristles, while the potatoes pass on to be bagged at the end of the chute. Later the stones are dropped by the brush.

This machine was not apparently wholly successful, but further work has been done on it and a modified or improved version has now been made. I am told by a person who was at a private try-out that it worked well—so well in fact that the bags had to be changed every 15 seconds. It has therefore been decided to fit the delivery end with a shoot or conveyor for delivery of the potatoes to an accompanying lorry.

I realise that there are many features of the horticultural industry with which I have not been able to deal, such as the large-scale dusting (see Figs. 7 and 8) and spraying of crops, artificial rainfall, and the more modern aspects of glass-house heating depending on the use of steam generated in a central boiler-house by a large thermally efficient boiler.[1] It is impossible, in so short a space, to cover the whole of such a wide subject. I have therefore concentrated on those aspects of mechanisation that I thought would concern the majority of horticulturists.

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[1] All these subjects are dealt with in other articles in this volume. *Editor—S.H.*

TOMATO NUTRITION

by

O. OWEN, M.Sc., Ph.D., F.R.I.C.

(Experimental and Research Station, Cheshunt, Herts.)

FOR many years tomatoes have been the principal crop grown under glass, and no serious change in this state of affairs can be foreseen for some time to come. No apology, therefore, is necessary for the title of this paper. Potash, nitrogen and phosphate are the main nutrients added and a discussion of these three constitutes the chief subject-matter.

Potash

It is often maintained that when supplies were free of restriction the amount of potash used for tomatoes under commercial conditions was excessive, and it may not be out of place to recapitulate some of the reasons why liberal dressings of potash are, in fact, necessary. These can be conveniently discussed under three main heads:

(*a*) Potash actually removed by the aerial parts of the plant;
(*b*) the amount lost in drainage;
(*c*) potash in relation to the quality of fruit—in particular, to blotchy ripening.

(*a*) Analyses of whole plants at Cheshunt showed that a reasonable crop (including fruit and foliage) removed from the soil potash of the order of 670 lb. per acre of K_2O. Lewis and Marmoy (*J. Pomology*, 1939, **17**, 275) growing a different variety under quite different conditions conclude that the removal amounts to 600 lb. to 700 lb. per acre per annum.

It may be suggested that these quantities represent luxury consumption of potash but this aspect is dealt with under (*c*) below.

(*b*) Lysimeter studies at Cheshunt show that during the growing season the loss of potash in the drainage amounted to 270 lb. K_2O per acre per annum. It must be emphasised that this loss does not include any losses which may occur during winter flooding, which is the standard commercial practice. In the course of this winter flooding from 80,000 to 150,000 gallons of water per acre are applied, the actual amount depending on the texture of the soil and the history of the preceding crop. No lysimeter measurements have been carried out during this flooding, and the actual loss of potash is problematical. Soil analyses before and after flooding show that there may be a reduction of as much as 0·03% in the water-soluble K_2O and differences of the order of 0·022% and 0·025% are common. If it be assumed that an acre of soil weighs 1000 tons these figures indicate a loss of between 490 and 670 lb. Taking a value of 500 lb. the total loss in drainage is 770 lb. K_2O per acre.

Paper read at the Revision Course in September 1946.

On the basis of these figures the potash requirements amount to 770 plus 670 making 1440 lb. K_2O per acre per annum. As a matter of passing interest it is noteworthy that, as a result of extensive empirical experiments, 1450 lb. to 1500 lb. K_2O per acre per annum have been found necessary for deep-rooting varieties of tomatoes. This, of course, corresponds to an annual consumption of sulphate of potash of about 30 cwt. per acre.

(*c*) Trials conducted over many years at Cheshunt have shown that as far as fertiliser treatment is concerned the major element in the incidence of blotchy ripening is potash. I have selected eight consecutive years, and during that time the percentage of blotchy fruit in the whole crop ranged from 8·92% to 45·61% where potash was omitted, while in the control plots receiving 'complete' artificials the proportion of blotchy fruit ranged from none (twice) to 6·36%. If this conclusion required confirmation it was supplied by experiments in which what had been a 'no potash' plot was divided and sub-plots received graded amounts of potash. Figures for one year were:

Potash added in mixtures	*Blotchy fruit*
None	37·81%
7½%	5·62%
10 %	2·62%
12½%	0·65%

In this connection an important consideration from the commercial point of view is the fact that a great proportion of this blotchy fruit occurs on the first and second trusses of the plant. In normal times these two trusses are often the most valuable trusses on the plant.

It should be noted that all these experiments were carried out on deep-rooting varieties. It so happens, however, that in quite a different connection a crop of Potentate deliberately kept rather, but not acutely, short of potash showed blotchy ripening to the extent of over 10%, whereas a crop adequately supplied with potash showed less than 5%.

Thus any attempt to cut down the potash applied to a tomato crop is attended with some risk. We propose to attempt to cut down the losses during winter flooding in the near future, but cutting down drainage losses during the growing season is much more involved.

It may well be asked why crops have done so well during the war years when potash supplies have been restricted. There are several answers to this question, and the chief one is that before the war potash applied was, in fact, often greater than the quantity mentioned, and consequently many glasshouse soils had a high reserve of potash. This has been confirmed in our analytical experience, and it is only within the last eighteen months or so that potash values in glasshouse soils have fallen to a low level, and during that time there has been a serious increase in the number of complaints of blotchy ripening.

Finally, there are two other points concerning potash. It is true that excess of potash does reduce the total crop, and before the war it was usual to attempt to strike a balance between sufficient potash to eliminate blotchy ripening and an excess which might reduce yield.

The second point concerns the alternative to sulphate of potash for tomatoes. Potash salts have proved to be harmful under glass. Wood and plant ashes are beneficial. Experiments comparing muriate with sulphate show repeatedly that there is little difference for both E.S.1 and Potentate, a slight advantage resting with the sulphate. The maximum effect of muriate on the plant consists of a slight yellowing of the foliage. This is perceptible in the case of Potentate but barely so in the case of E.S.1. Where the water supply is reasonably free from chloride this lack of colour soon disappears and there is no undesirable accumulation of chloride in the soil.

Nitrogen

Crop consumption at Cheshunt has been found to be of the order of 340 lb. of nitrogen per annum. Lewis and Marmoy (*loc. cit.*) give a value of 300 lb. Losses in drainage during the growing season correspond to 34 lb. of nitrogen per acre per annum. It is probable, therefore, that the total consumption of nitrogen at the time our experiments were carried out was under 400 lb.

Periodic determinations of the nitrate-nitrogen in soil under different manurial treatments lead to two general conclusions:

(1) There is a gradual accumulation of nitrate-nitrogen during the winter fallow period; and
(2) there is always a heavy fall in the nitrate-nitrogen concentration after heavy watering.

The nitrate accumulation referred to is reflected in the fact that for a number of years the crops picked during May and June from 'no-nitrogen' plots were of the same order as those picked from plots receiving complete artificials. After June the effect wears off, and usually the plants receiving no nitrogen die prematurely.

With regard to the fall in nitrate values it is clear that despite regular top dressings the high values of the early part of the season are never regained during that particular season.

In the traditional system of 'dry' growing, heavy watering is not practised until April, and as a result low values for nitrate which follow are liable to persist unless nitrogen is applied. Consequently there is the serious risk that the fifth and sixth trusses are being laid down in the plant when the nitrate level is unduly low. Hence there is an imperative need to supply nitrogen sufficiently early to eliminate this risk. In passing, it should be noted that another potent factor at this stage is the condition of the subsoil.

Apart from the commercial importance of these implications there is also the question of the fate of the nitrate which disappears. Lysimeter

experiments showed that practically the whole of the nitrogen in the drainage was in the form of nitrate. Nitrites were always absent, but there were present small amounts of ammonia and of organic nitrogen. The outstanding fact, however, was that the large falls in the nitrate-nitrogen in the soil were never accounted for by the nitrate which was found in the drainage. A further development of this work showed that even when the soil was wetted so as to avoid drainage there was a reduction in nitrate. On one occasion wetting brought about a reduction of nitrate-nitrogen from 188 to 100 parts per million, and on another from 64 to 35 parts per million in the soil.

One practical effect of this reduction of nitrate values is worthy of mention. Reference has been made to the effect of low nitrate on the well-being of the trusses at the middle of the plant. This applies particularly to the deep-rooting varieties which are often grown with comparatively little watering for six to seven weeks after planting. Not so Potentate, however, and this variety and those raised from it require continuous watering very soon after planting. As a result there is liable to be a shortage of nitrate comparatively early on. There is therefore the need to feed this and similar varieties much earlier than the deep-rooting varieties of the Ailsa Craig type. Hence also the preference Potentate has for soils rich in nitrogen and for mixtures containing appreciable amounts of such materials as dried blood.

To sum up, the main need for potash is during the early stages of growth and for nitrogen later on. This is supported by analytical data which show that the K_2O/N ratio in the plant is at a maximum during May and, of course, the conclusion is in accordance with commercial experience.

Phosphate

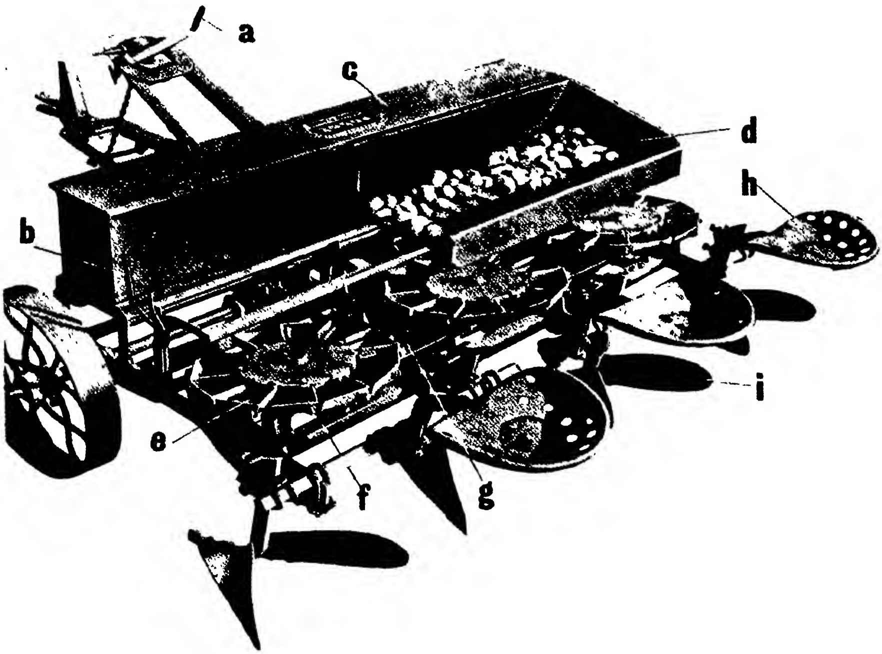
Actual consumption is low compared with potash and nitrogen, and under Cheshunt conditions amounts to 75–100 lb. P_2O_5 per acre. Lewis and Marmoy (*loc. cit.*) put it at the higher value of 125 lb. per acre per annum. Amounts lost in drainage are negligible.

Probably the greatest need for phosphate is in the very early stages and we frequently find that retardation of growth during the propagating season is due to inadequate soluble phosphate. It sometimes happens, too, that there is need for phosphates during midseason, particularly if there is need to induce new rooting. Apart from these two periods, however, the demands for phosphate are low and in many glasshouse soils there is adequate phosphate for the tomato crop.

Organic Matter

For tomatoes growing in soil it is general experience that regular application of organic matter in some form or other is essential. At Cheshunt we have had a plot which has been dressed with inorganic complete artificials for many years, and for some time now it has been little better than a corresponding plot that has been unmanured during the same time.

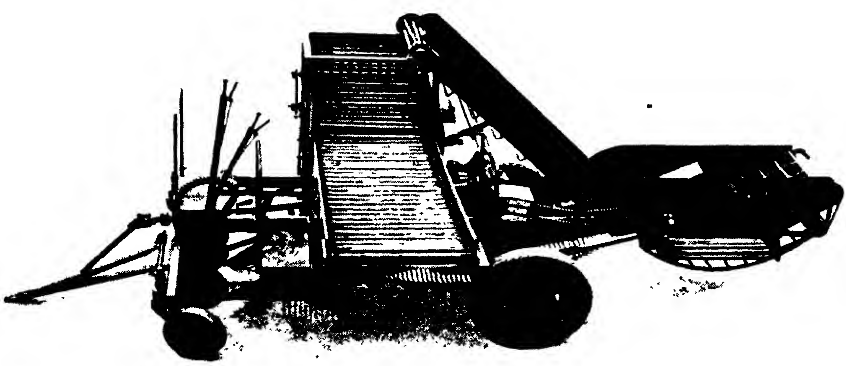
PLATE III (C. E. ELMS)



(*By courtesy of Transplanters (Robot) Ltd., St. Albans*)

FIG. 5. THREE-ROW POTATO PLANTER

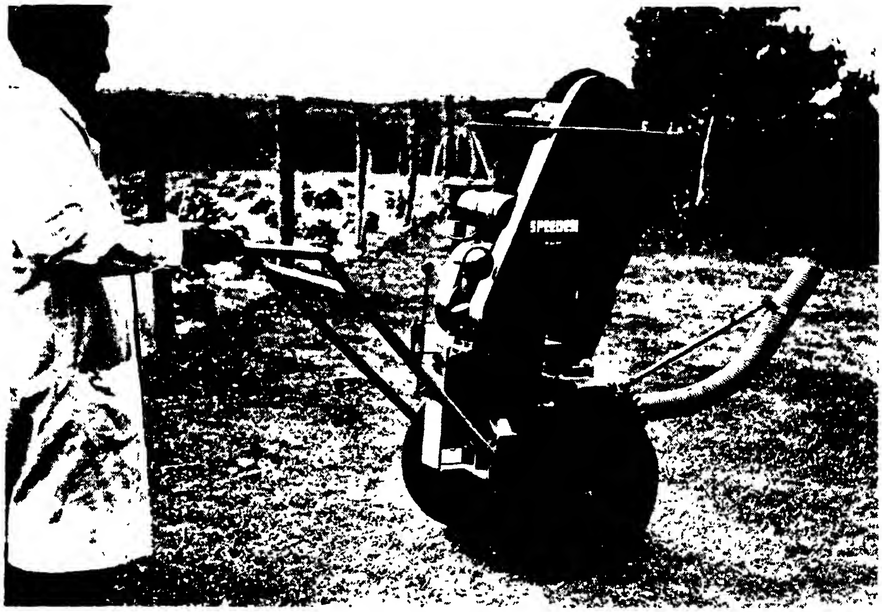
Allows full use of tractor tool-bar for after cultivations



(*By courtesy of Johnson's (Engineering) Ltd., March*)

FIG. 6. A MODERN POTATO HARVESTER

PLATE IV (C. E. ELMS)



(By courtesy of E. Allman & Co., Chichester)

FIG. 7. MANUALLY PROPELLED DUSTING UNIT FOR FRUIT TREES

(By courtesy of E. Allman & Co., Chichester)

FIG. 8. DUSTING MACHINE EMPLOYING THE TRACTOR EXHAUST TO BLOW THE DUST
Wide range of dusting rate is easily obtained

Extensive experience under commercial conditions suggests that what is required is a judicious mixture of organic and inorganic material.

Magnesium

During recent years there has been a serious increase in the incidence of magnesium deficiency in tomatoes. This is frequently attributed to the use of excessive amounts of potash. This view would appear to be supported by analytical data for tomato tissue but does not fit in with the following facts.

(1) In the Lea Valley potash was used extensively before the war. In fact, it would probably be true to say that more potash has been applied per unit area than in any other part of the country. Yet magnesium deficiency is comparatively rare.

(2) This particular deficiency has increased steadily during the war years when supplies of potash have, in fact, been decreasing.

With regard to the correction of this condition, my experience has been that application of up to one ton per acre of Epsom Salts in the base delays the appearance of the symptoms but does not eliminate them. Application of 15 cwt. per acre per annum for three years has given the same results in a nursery where the deficiency had been very pronounced for several years.

Spraying with Epsom Salts solution has, however, given satisfactory correction. The solution contains 2% by weight in water plus a wetter. Spraying starts when the characteristic yellowing first appears, and is repeated periodically. In really acute cases spraying every fortnight has been necessary but often it is sufficient to spray every three weeks, and it is continued for fifteen or sixteen weeks.

Manganese

Deficiency of this element is comparatively rare in tomatoes and where it has occurred correction has been effected by one spray with a 0·75% by weight of manganese sulphate to which a wetter has been added.

Soil Reaction

The majority of cultivated tomato soils under glass have a pH value between 7 and 8, and it is sometimes suggested that these high values are definitely harmful. While this may be true under some conditions it is not always so and some outstanding crops are produced in soils with a high reaction value. This is illustrated by the following data. In 1942 at Cheshunt in two houses the crop of Potentate ranged from 67 to 80 tons per acre and pH values of the soil at the end of the season from 7·69 to 7·91. E.S.1 in an adjoining house ranged from 64 to 67 tons per acre and pH values here from 7·69 to 7·93. It may be added that these houses had been in continuous cultivation for twenty years.

RAPID TISSUE TESTS FOR MINERAL NUTRIENTS IN PLANTS

by
D. J. D. NICHOLAS, B.Sc., Ph.D., A.I.C.
(Long Ashton Research Station, Bristol)

In recent years interest has been focused on the use of rapid chemical tests to assess the mineral status of soils and plants. Some pioneer work on the application of quick tests to soil extracts and plant tissues has been carried out by a number of American workers. Among the main contributors are Hoffer (1), Emmert (2), Morgan (3) and Thornton (4).

The extensive use of the visual diagnosis method for the identification of mineral deficiencies has emphasised the need for a quick tissue-testing system to confirm the former diagnostic technique. Investigations on chemical tissue tests commenced at Long Ashton during 1943. A tissue test technique (5, 6, 7, 8) has been devised for the diagnosis of mineral deficiencies in the field. The rapid chemical method is applicable to fresh plant material and it combines the advantages of simplicity of operation, minimum of apparatus and time economy over the method of full chemical analysis of the dry matter.

Tissue testing entails the extraction of the easily soluble nutrients from fresh plant material and the subsequent testing of the extracts chemically. Its value as a diagnostic method is based on the fact that the extractable nutrients from healthy versus mineral deficient plants usually show significant differences for the limiting mineral element. Toxicity levels of nutrients can also be detected by comparison with normal plant extracts. It is essentially a semi-quantitative method that can be readily used in the field with the minimum of time and apparatus.

Technique of Chemical Tissue Tests

Sampling Procedure.—Leaf samples collected must be taken from fixed positions so that they are comparable in size, maturity and probably in metabolic activity. This is important as there is usually a nutrient gradient in crop plants, *e.g.*, higher potassium content in younger as compared with older leaves and vice versa in the case of calcium.

For potato, tomato and hop, etc., leaves comparable in maturity are taken from the mid-stem position. When sampling cereals the internode adjacent to the growing point is used, but at the very young stage the first formed leaf may be used. With the onion the leaf bases are used in all instances. Consistent results with cauliflower, sugar beet and mangold are obtained by using the first leaf after the seed leaves. With fruit trees, however, leaves from the base of the new leader growths are usually the best test samples.

Paper read at the Revision Course in September 1946.

When collecting material for making comparisons between experimental plots, random leaf samples are taken; for the diagnosis of deficiencies in the field the procedure followed is to make comparisons between good and poor specimens.

Preparation of Test Samples.—In the preparation of samples for tissue testing the stalk or petiole portion is usually taken in preference to the leaf blade, since it contains less green colouring matter and more conducting tissue. Tissue test and complete chemical data justify the choice of petiole material as both methods agree that it reflects the nutritional status of the plant as efficiently as the leaf blade. In testing brassicae the midrib portions of comparable girth are used. The stalk portions are weighed (½ gram per test) and then cut up into approximately 2 mm. portions on a tile using a sharp scalpel.

For the extraction of the easily soluble nutrients from plants, two solutions are recommended. Morgan's Reagent is used for the extraction of potassium, magnesium, calcium, phosphorus, nitrate nitrogen, chloride and for manganese when this is present in excess. For the detection of manganese deficiency levels a purified Morgan's solution is made up. Hydrochloric acid (conc.) is used for the extraction of iron and zinc, the latter when present at toxic concentration.

Chemical Tests.—Details of the chemical tests used have already been published (5) and will only be mentioned here. The Long Ashton Tissue Test Outfit has been designed in conjunction with Messrs. Tintometer, Salisbury. This is a useful portable set that can be used in the field.

Nutrient tested	*Reagents*
Potassium	Sodium cobaltinitrite and isopropyl alcohol.
Calcium	Ammonium oxalate.
Magnesium	Titan yellow[1] and caustic soda.
Nitrate Nitrogen	Phenoldisulphonic acid and ammonia.
Phosphate	Ammonium molybdate, hydroquinone potassium carbonate and sodium sulphite.
Chloride	Silver nitrate and nitric acid.
Manganese (present in excess)	Formaldoxime and caustic soda.
Manganese (at deficiency levels)	Tetramethyldiaminodiphenylmethane[2] and potassium periodate.
Iron	Potassium thiocyanate.
Heavy Metals (present in excess)	Dithizone.
Copper (present in excess)	Sodium diethyldithiocarbamate.

[1] *Titan Yellow* of pre-war Grübler grade has been used at Long Ashton and proved reliable. Other batches may vary in strength and quality, and must be recrystallised and standardised before use.

[2] *Tetramethyldiaminodiphenylmethane* should be recrystallised from methyl alcohol before use. The tissue extract should be chilled in ice for 10 minutes before test.

Zinc (present in excess)	Cobalt acetate, ammonium thiocyanate and mercuric chloride.
Cobalt (present in excess)	Nitroso-R-salt.
Nickel (present in excess)	Nitroaminoguamidine.
Lead (present in excess)	Sodium sulphide.
Chromate (present in excess)	Diphenylcarbazide.

Diagnostic Value of Tests

It has already been mentioned that within a short time a confirmation of the visual diagnosis can be obtained using the described tissue test technique. Straightforward deficiencies of potassium, magnesium, phosphorus, nitrogen, calcium and manganese as well as toxicity levels of manganese, chloride and zinc can be readily confirmed. Another important feature is that the inter-relations of the soluble nutrients can also be studied, e.g. high manganese and low calcium; high potassium and low nitrogen levels can depress magnesium; low potassium may lead to higher calcium, magnesium, nitrate and phosphate values.

It should also be mentioned that tissue test results often give a clue to an impending mineral deficiency prior to the development of the starvation symptoms. It is therefore an early diagnostic method, as in some instances a deficiency can be remedied before the onset of the visual symptoms. A knowledge of the seasonal nutrient cycles in crop plants is essential for early diagnostic work, so that the value obtained can be related to the seasonal trend. The following example will illustrate this point. A 'medium' tissue test value for potassium obtained in potato during early May is usually serious, as it heralds the approach of potassium deficiency, whereas a similar value in late August can be the natural outcome of the downward seasonal trend. An intensive study has been made of the seasonal nutrient cycles in a number of crop plants under various nutrient treatments to determine at every growth stage a mineral deficiency as distinct from a seasonal effect.

A tissue test is of value for zinc when present in excess in plant tissues. Zinc toxicity has been reported from the Mendip country of Somerset and from parts of North Wales, where zinc deposits occur naturally in the soil, as well as from certain areas adjacent to industrial plants and when untreated industrial sewage has been used on arable land. Furthermore a high iron tissue value in the affected specimens confirms zinc poisoning as an excess of the latter is conducive to the accumulation and the immobilisation of iron in the tissues. The affected specimens usually exhibit visual signs of iron deficiency as the result of the unavailability of iron within the plants.

High levels of manganese are usually recorded in tissue extracts when certain plants, viz. brassica and potato, are grown in sharply acid soil: high manganese associated with calcium deficiency is responsible for the so-called 'acidity' symptoms in many field crops (9). Excess chloride can readily be detected in a number of crop plants when heavy dosages of

potassium or sodium chloride have been incorporated in fertiliser programmes. Red currant is particularly susceptible to chloride injury.

The tissue test method should also be of value in ecological work and in studying the distribution and translocation of nutrients in various plant organs.

Limitations of Tissue Tests

When a mineral element is deficient in plants, lower tissue test values are usually recorded for the particular nutrient as compared with those of healthy specimens. Iron does not conform to this rule. This is due to the fact that seldom is true iron deficiency operative under field conditions but rather is it induced by other nutrients, e.g. high lime, or in special instances by high zinc or copper levels. This results in the immobilisation of iron in the tissues and although there is usually abundant iron present it is not 'active' and hence visual signs of the deficiency are produced. The tissue test for iron may be used to confirm zinc toxicity in plants as such material usually contains higher amounts of iron as compared with healthy specimens.

The nitrate test can only be used as an indicator of the nitrogen status of most crop plants during the early growth stage. It is usual to find that as the plants mature the nitrate seasonal cycle falls abruptly and there is little nitrate present in many crop plants from mid to late season. There appears to be a correlation between wet conditions, which probably inhibit the activity of the nitrifying bacteria in the soil, and low nitrate values within the plant. Should nitrogen deficiency be operative a diagnosis can be made by tissue test early in the season.

It has not been possible to adopt a chemical method for the detection of boron in tissue extracts. This is partly due to the fact that the known methods are not sensitive enough to detect minute quantities of boron. Most of the existing methods require a refined technique involving the use of a 98% sulphuric acid for the development of the boron quinone colour complexes.. However, work in progress with turmeric powder indicates that deficiency levels of boron can be detected with this reagent in certain plants.

Correlation with other Diagnostic Methods

In trying to assess the value and reliability of the tissue test method it is essential to correlate the data obtained with those of other diagnostic methods. Some of the recognised methods used in the diagnosis of mineral element deficiencies in crop plants are (*a*) visual method, (*b*) spray or injection of deficient plants with the requisite salts, (*c*) full chemical analysis of normal as compared with affected specimens. Soil analysis can also give added support to the above methods especially in connection with potash, phosphate and lime deficiencies.

In practically all instances there is a very close correlation between tissue test results and the visual signs of a nutrient deficiency or toxicity.

Threshold values have been fixed which usually coincide with the appearance of the visual symptoms. Tissue test results often give a clue to an impending nutrient deficiency prior to the onset of the visual symptoms. The exceptions have already been mentioned, viz. iron deficiency, and nitrogen deficiency late in the season. In these instances the visual method is more reliable.

Full chemical analysis of the leaves is a recognised diagnostic method. It involves a chemical comparison of the total nutrient content of healthy and deficient plants, as a result of which significant differences are usually obtained for the limiting nutrient (excepting iron). The tissue test results for the 'soluble' unassimilated nutrients are usually in accord with the full chemical data, the latter representing the total nutrient content. In most instances there is a linear relation between the two chemical methods.

In general, tissue test results for plants growing on well-established manurial plots usually reflect fertiliser treatment and agree with the soil analysis. In conclusion, it may be claimed that this technique has proved invaluable for rapid diagnostic work and has played an important part in resolving nutrient disorders in farm and garden crops. It is an early diagnostic method and can in some instances be used prior to the onset of visual signs. It is particularly useful when the visual symptoms are not well defined or are masked by damage caused by fungi, insect or virus disease.

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PLANT INJECTION METHODS

by

W. A. ROACH, D.Sc.

(East Malling Research Station, Kent)

APPLICATIONS of plant injection to mineral deficiency work are based on a few very simple facts. Plants when cut, far from bleeding like animals, usually suck up any watery liquid bathing the cut. The liquid so absorbed travels along paths that can be predicted beforehand, so that by making the cut in the correct position it is possible to permeate a selected portion of the plant and leave a similar neighbouring portion untreated for comparison. The effect of nutrient solutions so absorbed is seen within a fortnight as an improvement in colour or appearance of the leaf or an increase in growth and often in both. Such improvements are usually preludes to improvement in commercial performance.

The mineral deficiency team at Malling makes use of other methods but it concentrates mainly on plant analysis and plant injection as complementary preliminary methods of diagnosis. Most of these are preliminary because no diagnosis can be called final until there is proof that treatment leads to a cure. The measurement of the effect of treatment suggested by the preliminary diagnosis on yield and quality of crop is, therefore, looked upon as the final and all important part of the diagnosis.

Methods

The methods are described in detail elsewhere.[1] Only a general description of them will be given here.

In all the methods actively growing leaves are desirable and usually are essential for success. It is no easier to make a mature leaf respond to injection than to teach an old dog new tricks.

Interveinal Injection.—If a small wound be made equidistant between two side veins and the mid-rib of, say, an apple leaf and the wound kept moist by a suitable wick passing through it and immersed in a nutrient solution, the solution is sucked into the leaf and permeates an area bounded by the mid-rib and the two side veins for at least half their length (Fig. 9). The effect of the solution can then be observed by comparing the permeated interveinal area with the one on either side of it. The treated and untreated areas are separated by a thin vein only. The slightest change in colour is therefore easily detected. Iron deficiency has been diagnosed in

[1] ROACH, W. A. (1939). Plant injection as a physiological method. *Ann. Bot. N.S.* 3, pp. 155–226. (A limited number of reprints obtainable from the author). ROACH, W. A., AND ROBERTS, W. O. (1945). Further work on plant injection for diagnostic and curvative purposes. Technical Communication No. 16 of the Commonwealth Bureau of Horticulture and Plantation Crops, obtainable from C.A.B. Central Sales Branch, Penglais, Aberystwyth.

an almost completely yellow leaf in two days. If the leaf is an 'off colour' green a change of colour is usually not visible for five days or a week.

Leaf-tip Injection.—Cereals and other similar monocotyledons may conveniently be treated by splitting a suitable leaf in half lengthwise for half its length by pushing a pin through the mid-point of its mid-rib and running it along to the tip. The tip of one half of the leaf is then immersed in liquid held in a suitable container and secured in position. The solution is sucked back for about half the length of the leaf and the effect may be watched by comparing the treated with the untreated half.

In a number of experiments on cereals a slight improvement has followed the injection of water. It is therefore necessary to do a water injection as a 'control' in such experiments.

Leaflet-stalk Injection.—If the blade of a leaflet half-way along the side of, say, a potato leaf is cut off and the leaflet-stalk be bent so as to dip into a suitable container of liquid, the liquid is sucked back into the leaf. If the container is removed after an hour the leaflets immediately above and below the injection point are the only ones that are permeated. The effect of the absorbed liquid may be observed at the end of a week or fortnight by comparing these two permeated leaflets with the two corresponding ones immediately opposite them on the other side of the mid-rib (Fig. 10).

Leaf-stalk Injection.—If the blade of an apple leaf be cut off and the leaf-stalk remaining on the shoot be bent so as to immerse the cut end in solution held in a suitable container the solution is sucked back into the shoot and is distributed according to a definite pattern in the leaves above and below. Usually the basal part of the first and second leaves above and below the injection point is permeated on the side nearer the injection point and is unaffected on the more distant side. (Occasionally the first leaf is unaffected; in this event the second and third leaves are affected on the nearer side.) The apple, pear, plum and peach are all affected in this manner (Fig. 11).

Branch Injection.—Single branches may be injected independently of the rest of the tree. In this way it is possible to observe the effect of a treatment on the fruit and on shoot growth as well as on the leaves. On a spur-pruned apple tree it is often possible to find twenty or more branches for this purpose. The substance may be injected in either liquid or solid form. For the liquid method a hole about one-eighth the diameter of the branch is bored diametrically through at a suitable point and connected by means of rubber tubing to a reservoir containing the liquid. Enough liquid is usually absorbed in about a day. For the solid method more than one hole is usually necessary and of larger diameter than for the liquid method. Into each hole is inserted the correct number of tablets of the substance and the hole is closed with a cork. The tablets and cork are conveniently inserted with a specially constructed instrument (Fig. 12).

Whole Tree Injection.—Similar methods to those just described may be applied to whole trees either for experimental or, in exceptional circumstances, on a commercial scale.

Practical Use of the Methods

Some typical results obtained by the use of these methods will now be described briefly because they will indicate the type of problem for which they should be useful in the future. The results to be described first will be the earlier ones in which it so happened that the troubles were each due mainly to a single deficiency. After these will be described more recent problems that are more difficult to solve sufficiently completely for practical purposes.

Boron Deficiency in Apples.—The first really important result from the use of these methods was obtained by workers overseas. They found the cause of what was one of the most serious troubles in apples in various parts of the world to be boron deficiency. The trouble is characterised by a corkiness of the flesh especially near the core. One form consequently is known as 'corky core'. In Western Canada especially, the deficiency was so severe that many whole plantations of trees were at the point of death. The cause of the trouble was found in New Zealand and Canada at about the same time, and a little later in Finland, by injecting various substances into branches or whole trees and observing that each compound that contained boron lessened or cured the disease. The following season it was found that soil applications of borax or boric acid were effective except on very calcareous soils and that spraying was also effective. This problem, which was so serious as to be alarming, was thus solved almost completely in two years.

Although boron deficiency is common in other crops in Britain it has not been recorded in apples. But results to be published shortly by Levy suggest that a mild form of the trouble occurred on certain trees at Malling in 1938.

Indicator Plants.—Boron deficiency is not revealed by any distinctive leaf symptoms in apples, but lucerne, a plant commonly used as a cover crop in Western Canadian apple orchards, exhibits striking symptoms of the deficiency. The cover crop is therefore used as an 'indicator plant' on the assumption that if the lucerne suffers from boron deficiency the apple trees growing in the same soil will be similarly affected.

This assumption seems to be justified in this instance, but results obtained recently suggest that indicator plants must be used with caution. Potatoes, willow cuttings and oats were growing in three parallel rows two feet apart. The potatoes and oats showed the characteristic symptoms of manganese deficiency. Leaf injection with manganese sulphate gave a marked response in both potatoes and oats and spraying the oats resulted in their reaching maturity and producing a crop, whereas the untreated ones died at an early stage. The willow cuttings growing between the potatoes and oats and only two feet distant from them showed leaf symptoms closely similar to those of manganese deficiency in fruit trees. Yet the results of leaf injection left no doubt that there was no deficiency of manganese, but a severe deficiency of iron. Thus potatoes, willows and oats growing with their roots interlacing in the same soil were suffering

from two different deficiencies, the potatoes and oats from manganese, and the willows from iron deficiency.

Manganese Deficiency in Cherries.—Growers in the Sittingbourne district were seriously troubled by the fact that many trees, just when they should have come into full bearing, ceased cropping, and a little later began to die back. One large grower over a period of some 30 years had consulted all the experts who he thought might be able to help, and the trouble had been ascribed to various causes, including faulty drainage that commonly accompanies it. This grower alone had grubbed some hundreds of trees.

Spectrographic analysis revealed that manganese was lower in the leaves of affected trees than in those from neighbouring productive ones. The cherry has been a difficult subject for diagnostic injection because it does not always absorb liquid when injected in the usual manner. The results from this method were not clear cut but they suggested that there was a deficiency of both manganese and iron.

Separate branches were therefore injected in the winter by the solid method with manganese sulphate, ferrous sulphate and manganese sulphate plus ferrous sulphate respectively. The manganese sulphate produced a most spectacular improvement in the foliage that developed in the summer and a heavy crop of cherries was produced. Whole trees were next injected. Many of these that had borne no crop for years then bore twenty or more 'halves' of cherries. Many hundreds of cherry trees were injected by the growers to get a quick cure. Co-operation between advisory and research officers led to these results. In the meantime, spraying has been tried successfully as a curative method. A dilute solution (usually 0·5% manganese sulphate plus spreader) or a more concentrated solution (5%) in winter has been found effective. Spraying must be repeated every season and injection every four years. Growers seem likely to prefer spraying. Injection, especially by the solid method, is not to be recommended if any other method is effective, because it is both rather laborious and entails mechanical damage to the main stem of the tree. But until alternative methods were available growers were only too glad to bring their trees back into cropping by the solid injection method, and were not worried by the mechanical damage or the occasional gumming from the holes.

Other methods were also tried. These included the application of manganese sulphate to the soil. These all proved either ineffective or less effective than injection or spraying.

As a result of curing trees by injection and observing the leaf symptoms, it is now possible to diagnose manganese deficiency in cherries by such symptoms. A slight qualification of this statement will be made later, however.

Deficiency Problems in the Antipodes.—The foliage of a large number of peach trees in South Africa in 1938 was completely yellow, and the trees had ceased bearing. Many hundreds had already been grubbed. On one estate the results of leaf-stalk injections suggested that manganese

deficiency was the main cause of the trouble and iron deficiency a contributory cause. A few whole trees were injected with solutions containing both manganese and iron to determine the correct dosage. The grower concerned then organised the injection of over 300 peach trees by 'Cape coloured' labour at an inclusive cost of 3*d.* per tree. The following season these trees bore a full crop of peaches.

Extensive leaf analysis and leaf injection experiments carried out during a year's stay in the country revealed a number of deficiencies the most widespread of which were manganese, zinc and iron.

Workers in Western Australia have proved by injection methods that the serious and extensive dieback in apple and pine trees there was due to copper deficiency. Soil applications proved effective and the trouble has ceased to be serious commercially.

Potassium Problems in Fruit Trees.—As a result of war-time restrictions on the distribution of potassic manures, large areas of fruit trees are so deficient of potassium that they are likely to die before manure applied to the soil can become effective, unless some interim action is taken to save them. In the circumstances solid injection seems worth trying as an emergency measure.

In addition to the very striking leaf symptoms of potassium deficiency, there are commonly much less obvious ones of either manganese or iron deficiency. Leaf analysis has confirmed these trace element, as well as the potassium, deficiencies.

Results so far obtained suggest that it is even more important to cure the trace element than to cure the potassium deficiency. Curing the trace element deficiency seems to lead to a partial cure of the potassium deficiency without the addition of any potash. The best results have been obtained from treatment with trace element and potash.

This also is collaborative work between advisory and research officers. Much of it is being done in Essex.

Multiple Deficiencies in Fruit Trees.—Not far from the manganese-deficient cherries already described, there are growing cherries that exhibit leaf and other symptoms that are similar but not quite identical with those already mentioned. The trees are very variable and only a few whole tree injections were done. The results were as follows:

Manganese	Most striking improvement in the foliage colour.
Iron	Definite improvement but less marked than that due to manganese.
Manganese + iron	Better than either of above.
Zinc	Better than iron but less good than manganese.
Manganese + iron + zinc + boron	The best result of all. Leaves apparently perfectly healthy.

These results suggest at least a triple deficiency, but they are insufficient to establish the degree of practical importance of the different deficiencies.

Numerous examples have been obtained of fruit trees responding to leaf-stalk injections of two, three, or even more elements, but so far it has not been possible to establish the degree of importance of all the

'constituent' deficiencies. To do this for a complex plant like a perennial fruit tree presents a problem of considerable difficulty, but recent results on annual crops suggest that this problem may be well worth solving.

Early in the war, the Agricultural Research Council, with the backing of the Agricultural Improvement Council, set up a team at the East Malling Research Station to extend the use of plant analysis and plant injection methods to agricultural as well as horticultural crops. The remaining results to be described were obtained by this team. The results raise a number of points of interest to advisory officers.

Calcium-Magnesium Deficiency in Potatoes.—Early in the war W.A.C. in the south-west of the country ploughed up well over 10,000 acres of heath and other derelict lands. Many hundreds of acres of the potato crop were a complete failure. The team was asked to help. Most of the worst potato plants were badly stunted but exhibited no symptoms characteristic of any deficiency. Leaf samples from the poor areas all showed a low calcium content and rather more than half a slightly low magnesium content also. The preliminary tentative diagnosis was, therefore, calcium deficiency and possibly, in places, magnesium deficiency. The W.A.C. officers responsible for the potatoes quoted the dictum: "Potatoes do not need lime." Leaflet-stalk injections were done at the same time as the leaf samples were taken. On all the poor areas there were strong responses to calcium chloride and on those with a low magnesium content to magnesium sulphate also. The W.A.C. officers were impressed by the responses, but said that it did not necessarily follow that an improvement in foliage growth and colour would lead to an increase in crop. Their attitude to both diagnoses seemed quite reasonable and proper, and as soon as possible trial diggings were carried out to determine how far yield followed calcium content. The yields were quite according to prediction. The W.A.C. then acted with extraordinary energy. They applied limestone dust to the huge area for which it was advised, and an extra 3000 tons of potatoes were gathered the next season in consequence. Curing the calcium deficiency was estimated to have added 6 tons per acre of ware potatoes and curing the magnesium deficiency an extra ton per acre. These results followed a most happy co-operation between the W.A.C. officers and the research team.

Perhaps the most striking fact revealed by this piece of work is that a mineral deficiency, so severe as to cause a complete failure of crop, may not be accompanied by any distinctive symptom. As already stated, the plants were stunted but in other respects appeared quite normal.

Multiple Deficiencies in Romney Marsh.—Early in the war large areas of the famous pastures of the South Kent Marshes were ploughed up and arable crops planted. The yield of these was very patchy and often varied from very high in one part of a field to a complete failure in another part of the same field. Usually the good yield was on ground that was a little higher than that bearing the poor yield, but the difference in level usually amounted to a few inches only, and there was no obvious soil difference

to account for the difference in yield. The only symptoms of mineral deficiency seen were those of manganese. These were to be found in most seasons in nearly every field in the whole area. In field after field their intensity increased regularly as the crop decreased, and it was tempting to conclude that manganese deficiency was the main or the only cause of the falling off in yield on the poor areas. But this almost certainly is not so.

One reason for coming to this conclusion is that spraying with manganese sulphate raises the yield rather more on the relatively good than on the poor areas; and on the poor areas the increases in yield are only a fraction of what would be necessary to make them equal to those of the good areas. This conclusion is drawn from the results of most detailed experiments in which the effect of concentration of spray, period and number of times of spraying have been studied.

Leaf injections were therefore carried out and improvements in colour were obtained in wheat to all the elements tested, namely manganese, iron, zinc, boron, copper and nickel. Curative experiments on wheat, potatoes and broad beans have since proved that application of each of these elements has increased the yield to an economically important extent. Thus leaf injection revealed five deficiencies not revealed by any symptoms. Leaf injection also revealed manganese deficiency in crops that showed no symptoms of the deficiency, and spraying of such crops has raised the yield in four experiments from 32 to 36 cwt., from 34 to 37½ cwt. and from 47 to 56 cwt. per acre, increases of 4, 3½ and 9 cwt. per acre respectively. Thus there is a wide field of utility for such diagnostic injection methods on symptomless trace element deficiencies which these experiments have proved may cause serious losses in crop. It is hardly necessary to point out that most arable farmers are, in respect to the major elements, concerned entirely with symptomless deficiencies, though they would express the fact by saying that they are applying artificial manures to produce maximum crops of optimum quality.

Some of the results of a potato experiment are of particular interest. A field was selected for experiment because of the prevalence of the characteristic leaf symptoms of manganese deficiency. Spraying with manganese had a most spectacular effect on the appearance of the foliage. Yet there was no increase in yield. Spraying with zinc sulphate, in spite of having no noticeable effect on the foliage, increased the yield by 27 cwt. But when both manganese sulphate and zinc sulphate were included in the spray, the yield was raised by 4 tons (from 7 to 11 tons per acre). Thus it may be useless to spray according to diagnosis by symptoms, even when these are very characteristic, or according to diagnosis by spraying unless some other deficiency not detected by these methods (but revealed by leaf injection) is also made good. The results also suggested that if the remaining four trace element deficiencies diagnosed by leaf-injection methods had been completely cured the yield would have been doubled, at least.

The examples given will indicate the possibilities of injection methods for advisory work.

SOILLESS CULTURE

by

W. G. TEMPLEMAN, M.Sc., Ph.D.

(I.C.I. Research Station, Jealott's Hill, Bracknell, Berks.)

FOR many years plant physiologists have grown plants without soil in nutrient solutions for experimental purposes, but it is only within the last ten years or so that attempts have been made to use such methods for the commercial production of horticultural crops. Highly coloured accounts in the popular press followed the claims of Gericke, of California, that very high yields of certain crops had been achieved by soilless methods. Since these claims were made, a number of research workers and other experimentalists in Great Britain have investigated these commercial possibilities, and it is now possible to present some of the results.

There are two chief types of method which for convenience will be termed solution culture, and sand or aggregate culture.

Solution Culture

This system is the one used by Gericke. In essence, it consists of the growth of plants in a wire-netting basket containing peat or wood shavings which is suspended over a shallow tank of nutrient solution. The plants, raised in pots of soil or sand, are planted out in the bedding material, and the roots penetrate through into the solution. The solution is changed at intervals and it has been stated that adequate aeration of the roots is achieved by lowering the solution level and leaving an air space below the bedding material.

Extensive tests of this method were made at Jealott's Hill but no satisfactory results have been obtained. Whilst initial growth of tomatoes was good, later development was poor, and root development and growth were not healthy. To ensure adequate aeration of the culture solution involves extra equipment and upkeep. Other workers also have failed to get good results from this system, and it is concluded that it is unsuitable for British glasshouse conditions.

Sand or Aggregate Culture

In contrast to solution culture, a number of modifications of sand and aggregate culture are showing promise for horticultural use under glass. In this country, there is no point in soilless cultivation out of doors, although this may be possible overseas in special situations, e.g. where soil does not exist.

The modifications of systems which have been used differ chiefly in the way in which the nutrient solution is applied to the sand or aggregate in which the plants are grown. Thus there are: (1) the surface-watering

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system; (2) the automatic dilution surface-watering system; (3) the drip-culture system; (4) the sub-irrigation system, and (5) the dry application system.

Surface-Watering System.—Under this system, the plants are raised from seed or cuttings in sand, at first being watered with plain water, and later by dilute solution. When a suitable size is reached, the plants are transferred to large pots or beds of sand. Thereafter they are watered by hand with nutrient solution in sufficient quantities to feed them adequately. It is possible to improvise the bed in a variety of ways since no attempt is made to collect any small quantity of solution which may drain through. On a pot scale at Jealott's Hill, this method has given yields of 10 lb. to 11 lb. tomatoes per plant, and at a nursery where 600 ft. of sand bed was devoted to this system, average yields of 9½ lb. to 12¾ lb. per plant were obtained.

Excellent crops of Cheshunt Early Giant lettuce have been grown similarly after the tomato crops. Carnations also have been grown very successfully.

Automatic Dilution Surface-Watering System.—Following the satisfactory results obtained by hand operation of the surface-watering method, an automatic method of injecting concentrated nutrient solution into the main water supply has been devised in collaboration with the Candy Filter Co., Ltd., of Hanwell, Middlesex. The ordinary service water pipe is led through a closed tank (in order to allow the water to reach greenhouse temperature before use) into a water meter, and some of the pressure is by-passed through a filter to the diaphragm of a small 'Autominor' injection pump connected with a reservoir containing concentrated nutrient solution. The outlets from the water meter and the pump are taken into a cylindrical mixing chamber fitted with a single opening valve leading to a hose fitted with a rose. On opening this valve, the pump is automatically set in operation, and concentrated nutrient solution is pumped into the mixing chamber in direct proportion to the flow of water through the meter. The hose is directed on to the sand bed by hand. No satisfactory method of automatically distributing the dilute solution evenly over the surface of the bed has yet been devised.

This system reduces considerably the storage space necessary for solution, and has given good yields of tomatoes, and is being tested extensively for carnations. The equipment should be of value for the application of fertilisers in solution to plants grown in soil either by overhead irrigation or by ordinary surface application.

Drip-Culture System.—In this system, the nutrient solution is allowed to drip continuously from an upper reservoir on to the sand bed through which it percolates and drains to a sump underneath. The solution is periodically pumped back into the upper container. The solution is changed completely at suitable intervals. The actual dripping takes place from a series of jets placed at intervals along a feed line down the centre of the bed. The chief disadvantage of the method is the frequency with

which the jets become blocked. At Jealott's Hill, on a small scale, it has given excellent yields of tomatoes.

Sub-Irrigation System.—Instead of surface application of solution, the bed (here filled with $\frac{1}{8}$ in. to $\frac{3}{8}$ in. gravel or some other aggregate coarser than sand) is periodically flooded from below, and then allowed to drain. An electric pump is used to pump the solution up into the bed and a trip switch operated when the bed overflows stops the pump. The solution then drains down to the sump. The bed is flooded at intervals as required. This method has been extensively investigated in the Horticultural Department, Reading University, by Professor R. H. Stoughton, and at Bakeham Farm Nursery, Englefield Green, Egham, Surrey, by Captain S. R. Mullard. Tomatoes only have been grown by this method at Jealott's Hill, but at the two other centres, excellent crops of carnations, lettuce and tomatoes have been produced. As with drip-culture, this system demands a watertight arrangement and a relatively large storage space for dilute solution.

Dry Application System.—Beds of sand may be fertilised by dusting the dry nutrient mixtures on to the surface, and applying water as and when necessary. This method has not given good results with tomatoes at Jealott's Hill, but excellent results with carnations at a commercial nursery have been reported.

Nutrient Solutions

A wide variety of solutions has been proposed, and it is impossible to acclaim any one as being better than another in the present state of our knowledge. There are two important considerations to be borne in mind—the first that the bulk of the nitrogen of the solution should be in the nitrate form, and the second that the pH of the solution should be maintained at approximately 6·0. This latter requirement is easily satisfied by the use of an appropriate indicator (e.g. B.D.H. '567'), and the addition of dilute acid or alkali as required.

The following two solutions, prepared as far as possible from fertiliser grade materials, have proved satisfactory at Jealott's Hill for tomatoes:

I.	Nitrate of soda	0·875 oz.	in 10 gallons water.
	Superphosphate	0·563 oz.	
	Sulphate of potash	0·488 oz.	
	Sulphate of ammonia	0·125 oz.	
	Epsom-salt	0·375 oz.	
	Minor elements concentrate II	1/12 pint	
II.	Nitrate of soda	0·805 oz.	in 10 gallons water.
	Mon-ammonium phosphate	0·129 oz.	
	Sulphate of potash	0·594 oz.	
	Nitrate of lime	0·101 oz.	
	Epsom-salt	0·393 oz.	
	Minor elements concentrate II	1/12 pint	

Minor elements concentrate II is prepared as follows:

Boric acid	21·5 oz.	in 200 gallons water.
Manganese sulphate	31·3 oz.	
Ferric citrate	205·5 oz.	

For solution I, it is necessary to stir up the required amount of superphosphate alone with water and, after standing, to decant off the clear liquid for addition to the other salts. The formulae given above are of solutions ready for use, but which need correction to pH 6.

Advantages and Disadvantages of Soilless Culture

As a result of the work so far, it is possible to state some of the advantages and disadvantages of soilless culture. The chief advantages are:

(1) The methods can be standardised and are characterised by an evenness of crop yield over an area of glass. The method used in one season can be repeated accurately subsequently.
(2) Crop yields in sand or aggregate have been as high and sometimes distinctly higher than corresponding crops in soil.
(3) Methods using automatic solution application reduce or eliminate the labour for watering and application of fertilisers.
(4) It is impossible to overwater and waterlog the roots since any surplus moisture drains away. The roots are excellently aerated. This means that hand application of nutrient solution can be done more quickly and with less skilled labour than is needed to water soil.
(5) Sand or aggregate beds do not require digging or any other cultivations and weeds are non-existent.
(6) Soil-borne diseases are eliminated to a very large extent, and in any case, sand and aggregate beds are very readily and quickly sterilised with formaldehyde. Sterilisation takes several days compared with perhaps weeks for soil. This means a great saving in labour and makes more cropping time available.
(8) The quality of crops of tomatoes, lettuce and carnations grown has been equal to the best grown in soil. Cultivation is very clean and this is important when growing flowers.

The chief disadvantages are:

(1) The high initial cost of equipment and of sand or other aggregate. Methods not needing watertight beds are much cheaper from this point of view than others.
(2) Some methods require the provision of large storage space for dilute solution.
(3) An electricity supply is needed for some systems.
(4) The soil with its complex colloidal system tends to rectify or ameliorate mistakes made in manuring, and acts as a buffer. In soilless culture, no such safety margin exists.

(5) Soil retains moisture longer than sand or aggregate. This means that application of nutrient solution has to be made more frequently than the application of ordinary water to plants grown in soil. Also the neglect of watering plants in sand or aggregate will have more serious and earlier effects than the same neglect of soil plants.

(6) In addition to normal horticultural skill, some additional technical control is required.

There is now no doubt that excellent crops of glasshouse crops can be grown by soilless methods. What is now required is that they should be tried by commercial growers, and their economics on a large scale studied. The Jealott's Hill Research Station Bulletin No. 2 giving existing information in detail has recently been rewritten.

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THE SPECIFIC USES OF DDT AND GAMMEXANE IN HORTICULTURE

by

G. FOX WILSON, N.D.H., F.R.E.S.

(Entomologist, Royal Horticultural Society, Wisley, Surrey)

HORTICULTURAL advisory officers are in a position to consult a considerable amount of the literature pertaining to the specific uses of these new synthetic insecticides, and this provides sufficient excuse for me to confine my remarks to personal observations and to discuss the results of tests carried out at Wisley rather than to review summarily their respective merits and demerits as outlined by various investigators. An introductory discussion on DDT by American entomologists appeared in 1944 (*Jour. Econ. Entom.*, **37**, 125–59), and will prove of general interest to advisory officers. These insecticides and their significance in agriculture have been reviewed by Shaw (13), while the Ministry of Supply has recently published a bulletin, entitled, *Some Properties and Applications of DDT*, which, however, has a limited appeal to the practical horticulturist owing to the sparseness of information relating to the effect of this insecticide upon indigenous pests.

A plea was made (9) that standardised formulations of DDT should soon be available to the agricultural and horticultural communities, and that such would be listed as officially approved products by the Ministry of Agriculture. A recent statement has been made by the Ministry (*Agriculture*, 1946, **52**, 527) to the effect that manufacturers may submit DDT and Benzene hexachloride in their several formulations for official approval. In this connection, the question of the more efficient products in relation to the advice given by advisory officers to growers may be raised here. Dillon Weston (8), in discussing the Ministry's approval scheme as seen by a specialist advisory officer, stated that the scheme was a meritorious one and enabled advisory officers to recommend without bias or favouritism those products that receive official approval. Unfortunately, however, the scheme "may defeat its own purpose by the sanctioning of a plethora of good, but not sufficiently good, products". This is due to the fact that the relative efficiency of proprietary preparations is not assessed—such being possible only by testing products under field conditions. The importance of field performance in the matter of insecticides and fungicides is all important, for only from trials made on organisms living under natural conditions in the garden, on the farm, and in glasshouses can a true assessment be made of them. It is the experience of advisory officers to find that the intelligent agriculturist and

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horticulturist desire the name of the more efficient brands, and dislike making a choice from a list of numerous preparations.

With these facts in mind, it is of field performance that I wish to speak, though my remarks will be confined chiefly to DDT products. The opportunity of assessing the value of Gammexane or to carry out comparative trials with both insecticides has not occurred until recently.

The great advantage that DDT and Benzene hexachloride or Gammexane—hitherto known as '666' and now as 'Agrocide'—have over plant alkaloids (and pyrethrum in particular) is that there is little risk of loss of toxicity and deterioration over long periods of storage. So stable and indestructible are these chemical compounds that the question of their toxicity to human beings still requires confirmation.

Both compounds may be prepared in a number of ways, including dusts, solutions, emulsions, suspensions, liquified-gas aerosols, and 'smokes' or volatilising generators. Numerous formulations are now available for use on the farm, in gardens, and for domestic purposes. With regard to the last-mentioned group, many familiar household insecticides have now incorporated one or other of these compounds in their preparations.

The action of both insecticides on pests is one of selectivity, and such pests as red spider mites are not affected, while others, especially aphides, are only slightly affected by the formulations now available. The more effective control of such pests as plant-parasitic Acarines may to a considerable degree be made possible by the addition of other insecticides, e.g. oil emulsions, lime sulphur and plant alkaloids (e.g. derris and pyrethrum), with all of which DDT is compatible.

Toxicity

Both the residual and the profound effects of DDT upon the nervous system of insects have directed the attention of toxicologists to the problem as to its effect upon warm-blooded animals, including man. The toxic manifestations of DDT have been discussed by West and Campbell (14), who in addition have surveyed the history, development, properties and application of DDT. Their book will prove an invaluable guide, not only to those advisory officers who are remote from libraries, but to others who are unable to spare the time to consult the voluminous literature on the subject.

The considered opinions of Buxton (2) in relation to DDT, and of Cameron (3) in relation to the risks to man and animals from the use of DDT and Gammexane, are that both insecticides are safe provided that the precautions dictated by common sense and experience are taken. Some of the reported toxic effects upon domestic animals, e.g. dogs and cats, by the application of these compounds for destroying ecto-parasites have undoubtedly been due to the use of incorrect formulations or to carelessness in applying correct dosages. It has been observed that potato tubers and carrots grown in land dressed with Gammexane against wireworms may, on occasion, be tainted and rendered extremely unpleasant to eat.

The potency of DDT to wild life, including fish, game, rodents, reptiles and amphibians, has been the cause of grave concern to American and Canadian workers, following the application of dusts and oil sprays to forests for the control of tree pests and to lakes and swamps against mosquitoes. The spray concentrations to such areas ranged from 0·2 to 5 lb. of oil spray and 25 lb. of dust per acre dispersed by airplanes (6). While the amount of DDT that actually reached the ground vegetation showed considerable local variation depending upon the rate of application, weather conditions, defective spray apparatus and different density of vegetation, there was a pronounced mortality in wild life from the use of the higher concentrations of DDT. It was found that invertebrates and cold-blooded vertebrates were more readily affected than were birds and mammals. The effect can only be ascertained by long-term investigations before a true evaluation is possible.

In the case of man, the directions in which present information is lacking are: (i) the accumulative effect of small doses as might arise in spray residues on fruits and leaf vegetables; (ii) the absorption of DDT in oil through the skin of fruits sprayed with these solutions; and (iii) the danger of long-continued exposure to spray drift on the bare arms and faces of men engaged in orchard spraying. Cameron (3) states that DDT possesses one advantage over Gammexane in that the premonitory signs of intoxication due to its absorption are well defined and occur with doses well below the fatal level.

Apart from the selective effect of DDT upon plant pests, its widespread toxicity to insects has given rise to a major problem, namely, to the destruction of beneficial species (parasites, predators and pollinators). This factor alone is sufficient to restrict its widest application to avoid upsetting the natural equilibrium between the insect host and its natural enemies on the one hand, and between fruit production and pollinators on the other.

For instance, we have found at Wisley as elsewhere that severe outbreaks of the fruit tree red spider mite followed summer applications of DDT against codling moth owing to the destruction of its natural enemies, chiefly anthocorid bugs. Careless timing, especially in the case of spraying fruit crops, may result in a high mortality to hive bees and other pollinating insects, including syrphids. Fortunately, this aspect is sufficiently appreciated by commercial growers and amateur gardeners alike owing to the publicity given to the dangers arising from the applications of both arsenicals and DDT to fruit crops immediately prior to and during the blossoming period.

Reports of phytotoxic injury to plants following the application of DDT have been made. Many such cases have arisen from the application of incorrect formulations, namely, of those intended for domestic use and prepared solely for destroying household pests.

Some American growers report complete loss of Kalanchoës from the use of wettable DDT spray powders and emulsions (1). The leaves are

stated to drop soon after the treatment or after a fortnight, and the plants die. This effect has not been produced on Kalanchoës sprayed at Wisley with a 0·2% DDT emulsion.

Wisley Investigations

These investigations comprised both laboratory and field tests on a range of plant pests, using: (i) 20% DDT emulsion diluted to give a wash containing 0·1–0·2% DDT; (ii) 25% wettable powder at a strength of 0·05–0·1% DDT; (iii) 5% DDT dust; (iv) 'smokes' or volatilising generators containing 11 grm. DDT per 1000 cu. ft.; (v) Benzene hexachloride 2% (0·26% 'Gammexane' content); and (vi) Benzene hexachloride 3½% (0·45% 'Gammexane' content). The principal toxic ingredient of benzene hexachloride is the gamma-isomer.

The results of these tests, which will now be considered, refer solely to their several field performances on insects, and other arthropods (acarines, woodlice and millepedes).

Insects

Thrips.—Effective control of the greenhouse thrips, *Heliothrips haemorrhoidalis*, has resulted from the application of 20% DDT emulsion diluted to contain 0·1% to 0·2% DDT. Atomised formulations would undoubtedly prove more effective in controlling outbreaks in glasshouses owing to the difficulty of directing the wash to the underside of the leaves of close-cropped plants.

Earwigs.—These pests have within recent years become increasingly important as defoliators and skeletonisers of vegetables (beans, carrot and parsnip in particular) and of ornamentals (Chrysanthemum and Dahlia), and an effective control is not possible with poison baits unless baiting campaigns are organised and undertaken on the widest possible scale. The nocturnal activity of earwigs misleads many growers in not associating these pests with certain crop injuries. Both DDT and Gammexane dusts and sprays have proved effective in avoiding injury by earwigs to vegetables and to ornamentals.

Hemipterous Bugs.—The immature stages of the Rhododendron bug, *Stephanitis rhododendri*, are readily killed by DDT sprays, but insistence must be made on the importance of directing the wash to the underside of the leaves where the Tingitids congregate and feed. This is due to the fact that the insecticide is not ingested by hemipterous insects, but acts as a nerve poison which necessitates contact with the body of the organism.

DDT formulations have effected satisfactory control of capsids, including the apple capsid bug (*Plesiocoris rugicollis*) and the tarnished plant or 'Bishop' bug (*Lygus pratensis*). The avoidance of malformed blooms on chrysanthemums was obtained this season with 0·1% and 0·2% DDT emulsions. Applications were made during July and August, the first taking place as soon as there was any sign of capsids on the plants.

Later, there may occur a massed migration of *Lygus* from weed hosts to cultivated plants, especially Chrysanthemum, and further sprayings are necessary to protect the newly formed growth and, in particular, the flower buds. The adult capsids died within an hour or so after receiving a complete wetting of the emulsion. While the addition of pyrethrins to DDT sprays resulted in a 'knock-down' effect both upon the immature, wingless and the adult winged capsids, DDT alone gave markedly good results and, in particular, from a protective standpoint. The application of a 5% dust, however, gave longer protection against attack, but is less popular with growers owing to the persistent nature of the dust, which is considered unsightly and reduces the market value of cut blooms.

White Fly.—The adult stages of the greenhouse white fly, *Trialeurodes vaporariorum*, are readily killed by DDT emulsions and 'smokes'. The earlier 'scale' instars are effectively controlled by direct contact with DDT sprays, but are tolerant of the vapour. White flies, together with *Encarsia*, emerged from their pupal-cases some twelve hours after fumigation (11 grm. DDT per 1000 cu. ft.), but the adult chalcids were killed.

Aphides.—The comparatively slow action of DDT upon aphides, whose specialised parthenogenetic method of reproduction during their spring and summer phases is not effectively inhibited, is a decided disadvantage. It occurred repeatedly that several species of aphides when sprayed with wettable DDT and emulsions succumbed so slowly that the viviparous females became moribund and underwent a protracted state of 'coma' for some hours prior to death, and permitted the reproduction of living young. The effect was a re-infestation of the plants within a few days.

The non-selective effect of DDT upon such species as the cabbage aphis, *Brevicoryne brassicae*, and upon woolly aphis, *Eriosoma lanigerum*, is that their natural enemies, namely hymenopterous parasites (*Aphidius* and *Aphelinus* respectively) are killed, together with such predatory enemies as Coccinellids and their larvae. The effect is that even higher populations of the pests are liable to be built up and tend to remain high until the natural equilibrium is restored.

It was found that dusts were more effective aphicides than wet sprays, and high mortality followed the application of 5% DDT and of Gammexane (Agrocide I) to broad beans infested with *Aphis fabae* and to ornamental Viburnum attacked by *A. viburni*, with a definite bias in favour of Gammexane in its rate of toxicity.

The dust that remained on the foliage and shoots appeared to exert a repellent action upon both the viviparous female aphides and upon the newly born 'lice'. This advantage is probably outweighed by the high toxicity of the dust to their parasitic and predatory foes.

The selective toxic effect of DDT upon aphides was marked, and a higher mortality occurred with the pear, *Anuraphis pyri*, and Viburnum aphides than was the case with the bean and peach aphides (*Myzus persicae*) and with *Myzus ornatus* following the application of liquid formulations.

Scales and Mealy Bugs.—While an effective control of first-stage larvae or 'crawlers' of the European brown or peach scale, *Lecanium corni*, and of the greenhouse mealy bug, *Pseudococcus maritimus*, followed the application of DDT emulsions, little effect was produced on the mature insects. This is probably due to the hard, chitinous texture of the scale with which the adult female is covered, and to the not readily wetted waxy nature of the body of mealy bugs.

On the other hand, the greenhouse scale, *Lecanium hesperidum*, was effectively controlled owing to the softer nature of its scale, and to the fact that this species reproduces viviparously. Pot-grown *Citrus* were cleared of scale infestations with DDT emulsions. DDT possesses no ovicidal properties so that the eggs of scales and mealy bugs are not affected. Those of the former are, moreover, well protected beneath the body of the adult female, while the latter, though exposed, are enmeshed in an ovisac of waxen threads.

Lepidopterous Pests.—Both DDT and Gammexane are unique in that they combine the properties of a stomach or internal poison with that of a contact wash, so that their application to plants attacked by openly feeding defoliating caterpillars is particularly successful. The effect of DDT sprays upon brassica pests has recently been discussed (12), but the persistent nature and residual effect of DDT raises the question as to the advisability of applying formulations to rapidly maturing leaf vegetables and ripening fruits. It is my considered opinion that such applications should not be recommended until such time as the toxicologist has completed investigations upon the toxicity of these insecticides to warm-blooded animals, including man.

DDT sprays and dusts have been found to be extremely effective for controlling the following species of lepidopterous larvae, namely, cabbage white butterflies, *Pieris brassicae* and *rapae*; cabbage moth, *Mamestra brassicae*; and diamond-back moth, *Plutella maculipennis*, on brassicas; tomato moth, *Polia oleracea*, on tomato; ermine moth, *Hyponomeuta cognatella*, or ornamental Euonymus; pyralid and tineid moths, *Eurhodope sauvella* and *Scythropia crataegella*, on Cotoneaster; and several leaf-eating caterpillars of such fruit pests as the winter, lackey and vapourer moths.

It was observed that the presence of DDT dust upon the foliage of brassicas, e.g. cabbage and kale, did not prevent egg-laying by cabbage white butterflies unless the deposit was thick or that the applications were sufficiently frequent to form a protective layer over new growth that is being developed at the time of intense ovipositional activity of the females.

Coleopterous Pests.—The number of beetle and weevil pests that are effectually controlled with DDT and Gammexane is high, and highly successful results have been obtained against such pernicious and hitherto only partially controllable pests as flea beetles (11) and apple blossom weevil (7). So effectively are these pests controlled by these insecticides that their applications to seedling brassicas and to apple trees should now

be considered as routine operations in vegetable and fruit gardens. The flea beetle trap is now completely outdated, and has been replaced by the flea beetle duster, which is a small 2-wheeled machine capable of distributing the dust along the rows of seedling brassicas in a band 5 to 6 in. in width and at the rate of 35 lb. to 40 lb. per acre. Spectacular results from the long-range drift effect of DDT sprays upon the incidence of apple blossom weevil on unsprayed outer rows of apple trees adjoining sprayed blocks are already familiar.

Hitherto, partial control only of the apple and strawberry twig-cutting weevils, *Rhynchites species*, has been possible with derris preparations, and preliminary investigations with DDT dusts indicate that these pests may now be effectively controlled. Similarly, attacks both of *Otiorrhynchus* weevil larvae in pots of Begonia, Cyclamen, Primulas and alpine plants, and of shot-hole borers in plums appear to be avoided by the timely application of DDT formulations.

The following species of flower- and foliage-devouring coleopterous pests have been effectively controlled with DDT, namely, the asparagus and lily beetles, *Crioceris asparagi* and *lilii*; the viburnum and water-lily beetles, *Galerucella viburni* and *nymphaeae*; garden chafer, *Phyllopertha horticola*, on apple blossom and fruitlets and rose blooms; and the bean and pea weevils, *Sitona species*, on pulse.

Success against the mustard beetle, *Meligethes aeneus*, has been reported (12), but here again a warning is issued of timely applications to avoid mortality among pollinating insects.

Investigations are in progress at many centres with a view of reducing wireworm injury to crops by the application of DDT and Gammexane dusts to infested ground. The results already obtained are sufficiently promising to indicate that the repellent action alone of these insecticides upon wireworms will allow plants to become established before an attack develops and to withstand attack for some considerable time after the dressings are made. The curious fact in relation to such dressings is the difficulty of finding dead wireworms in ground treated with Gammexane. Preliminary experiments at Wisley on the control of wireworms with both compounds suggest that the repellent action of both upon these soil pests is strong.

The raspberry beetle is another pest against which DDT has proved effective, but greater risks attend its use owing to the time of application both as regards toxicity to pollinating insects and to the residual effect upon the developing fruits.

Dipterous Pests.—DDT has proved an excellent leatherjacket exterminator, whether applied as an emulsion into the turf or dusted over the surface in the form of a dry powder (5). While November is suggested as the best month to carry out the treatment since the leatherjackets are then small and little appreciable damage has been done, good results followed the application of 5% dust at the rate of 2 oz. per sq. yd. to a cricket pitch in August when the larvae were fully grown. A liquid

emulsion is, however, preferred on bowling-greens as no visible deposit remains. The speed with which turf recovers once the larvae are exterminated is surprising, provided that sufficient water is available to irrigate the damaged area.

The effective control of sciarid and phorid flies in mushroom houses has hitherto been difficult, but the use of DDT sprays and 'smokes' has rendered possible the eradication of these pests in commercial houses. Less effective are the results from treating open frames and leaky sheds owing to the constant arrival of fresh invasions from natural breeding-sites.

There is evidence, also, that while timely applications of DDT sprays and dusts provide effective control of such vegetable pests as carrot flies, variable results have so far been obtained against the onion and cabbage root flies. Carrots treated with DDT emulsions were never found to be tainted in flavour, as is often the case with Gammexane and tar oil treatments. DDT dusts applied to celery plants before the first generation of flies appeared kept the leaves clear of leaf-mining maggots. Further dressings were necessary to protect the new foliage against the second and third generations.

Experiments carried out at Wisley this year indicate that attacks of the large bulb or Narcissus fly, *Merodon equestris*, are avoided by the application of a 5% DDT dust immediately the flies are observed on the wing. As this date varies from year to year, observations are necessary to time the applications to coincide with the period of emergence of the flies.

The matter of the control of house flies and mosquitoes may not be considered to be within the scope of this paper, but both may be regarded indirectly as horticultural pests. The former breed in manure heaps, and invade dwelling houses, especially those situated near stables, farmyards and manure heaps. The latter breed in ornamental pools, ponds and lakes, ditches, water-storage and liquid-manure tanks in and around glasshouses, and in water-butts, and the adults are a source of annoyance to those who work and walk in gardens. Furthermore, large concentrations of adult mosquitoes (e.g. *Culex pipiens*) overwinter on the dry warm walls of underground stoke-holes, and the treatment of such shelter-sites should be the concern of the owner.

The absence of any 'knock-down' effect upon flies may prove disappointing to those who have come to expect rapid death following the application of atomised fly-sprays. The addition of pyrethrins, however, to DDT formulations accelerates the toxic effect upon the insects.

DDT has long been proved to be an effective mosquito larvicide, and its great advantage is that low concentrations only are necessary to obtain an effective control of these pests. Again there arises the direct and indirect effect of formulations upon other aquatic animals, more especially fish and predatory insects (e.g. *Dytiscus* beetle larvae and dragonfly nymphs).

The indirect effect is that these voracious feeders of mosquito larvae may be affected through devouring those 'wrigglers' that are slowly dying from the effect of DDT sprays. It is advisable to withhold the application of DDT to ornamental waters stocked with fish until further investigational work is completed and official rulings are given as to correct dosages and formulations necessary to obtain an effective control of mosquitoes with the minimum danger to other denizens of the pond or lake. In the meantime, treatment of other breeding-places, namely, ditches, water-storage and liquid-manure tanks, and water-butts is recommended.

Hymenopterous Pests.—While no tests have so far been made at Wisley on the control of apple sawfly with DDT, workers elsewhere report somewhat disappointing results in view of the successful control of a pest with similar habits, namely, codling moth.

Completely effective control using 0·1% DDT emulsions has been obtained against the leaf-eating larvae of the Iris, Solomon's seal and Spiraea sawflies. The results of two years' investigations on the control of the rose leaf-rolling sawfly, *Blennocampa pusilla*, indicate an effective control of the adult sawflies with DDT formulations. Stress is laid upon the importance of timely applications against this pest, which should be destroyed in the adult stage before eggs are laid in the marginal leaf areas. DDT dusts will serve as a repellent to the egg-laying females though it is essential to protect the developing leaflets with a deposit of dust. The factor of importance is that leaf-roll occurs soon after the eggs are inserted within the leaf tissues and some time before the eggs hatch.

The earlier instars of the gooseberry sawfly, *Pteronidea ribesii*, are effectively controlled with DDT, but early application is advisable to avoid oil absorption by the developing fruits and of dust deposits on the foliage and fruits. Such precautions are unnecessary against the later broods of larvae which appear after the crop is harvested.

It is possible to destroy colonies of ground-building wasps, *Vespula germanica* and *V. vulgaris*, by placing a layer of DDT dust at the entrance to the nest. The effect is slow and activity may continue for as long as eleven days after treatment. Thus, there is no advantage over sodium cyanide solutions or even of derris dust.

Success against plagues of ants in gardens, frames and glasshouses is variable with DDT, but the application of a 5% dust at the entrance of the nest and along the main runs leading to it will occasionally prove successful. The effect, though slow, is surer than some of the remedies previously recommended against these pests. Invasions of the mound-forming turf ant, *Lasius flavus*, in lawns are controllable with DDT dusts, but disappointing results may follow its application to areas infested with the Pharaoh's or house ant, *Monomorium pharaonis*, in glasshouses and frames unless high rates of applications are made. The chief difficulty arises from the fact that it is impossible to reach even the perimeter of many nests of this species, which are constructed deep within the cavities of walls.

Other Arthropods

Red Spider Mites.—Small-scale tests on glasshouse plants (e.g. Carnation, Hydrangea and other ornamentals) and on apple trees against the greenhouse (*Tetranychus telarius*) and fruit tree red spider mites (*Oligonychus ulmi*) respectively showed that DDT both as dusts and as emulsions was an ineffective acaricide. High populations of the fruit tree red spider were rapidly built up on orchard trees following summer applications of DDT against codling moth. While a combination of DDT and the appropriate oils will largely overcome this selective toxicity, the natural equilibrium between the mite and its natural enemies is upset—a factor that has been discussed previously.

Woodlice.—These crustaceans are effectively controlled with 5% DDT dust, and no phytotoxic injury has followed its application to a wide range of plants, including alpines, ornamentals and vegetables. This treatment is specially valuable for treating breeding-sites in and around compost heaps and rubbish dumps.

Millepedes.—Preliminary experiments indicate that the spotted millepede, *Blaniulus guttulatus*, is intolerant of DDT formulations. The application of a 5% dust along the sides and bottom of seed drills in which broad beans and peas were sown and over lily bulbs planted in ground where the pests were abundant kept the plants clear of attack over a long period.

Severe injury is reported from many gardens, especially where the ground is overmoist through defective drainage or the physical nature of the soil, and in land where annual heavy dressings of organic manures have been given over a period of years. The former method of dressing seed drills with superphosphate was unsatisfactory owing not only to the phytotoxic injury that followed its application, especially to the developing plumules and radicles of germinating pulse, but to the retarding effect upon the growth of such seedlings.

Finally, with regard to another group of pests, namely, slugs and snails, DDT has little or no effect upon these molluscs either as a stomach poison when ingested with a suitable attractant, e.g. bran or bone meal, or as a contact nerve poison.

Equipment for Application

The apparatus for applying these insecticides as dusts and sprays ranges from the use of a fountain-pen filler for low dosages of DDT as mosquito larvicides to small ornamental ponds to dispersal by airplanes and helicopters over forests, lakes, swamps and large plantations. All the normal types of spraying and dusting equipment are suitable, including hand-dusters, knapsack blowers, rotary dusters, wheeled dusters and adapted seed-drills for dusts; and syringes, hand-worked and compressed air knapsacks, and high-powered spraying and atomising units for liquid formulations.

Aerosol bombs and sparklet sprayers are being developed in the United States and in this country to render possible the dispersal of DDT to pests other than house flies and mosquitoes. The aerosol technique is not sufficiently developed to warrant its use against pests other than household insects, but further investigational work on formulations will widen the scope of their employment to include plant pests, especially those occurring in glasshouses.

A more recent development in the dispersal of DDT and Gammexane has been the introduction of 'smokes' or volatilising generators suitable for fumigating glasshouses, mushroom sheds, seed stores, granaries and ships' holds.

The design and use of sprayers for insect control has received attention during the war following the demands of the Service Departments chiefly in relation to their use in the control of insect infestations of medical importance. A plea is put forward (10) for the designing of apparatus based on careful biological testing and sound engineering design rather than to attempt to adapt and improve upon existing proprietary equipment. The statement made by Cameron (*loc. cit.*) that "the mechanical construction of a great many commercial sprayers leaves a great deal to be desired" will be strongly supported by field workers and by those who have practical experience of spraying.

Summary

The introduction of DDT and Benzene hexachloride has considerably widened the field of chemical control of plant pests, but their limitations as general insecticides should be recognised. Neither possess any 'cure-all' properties, being only slightly toxic to aphides and some other insect groups, useless against plant-parasitic acarines, and without ovicidal properties.

Stress is laid upon the importance of preparing liquid formulations strictly in accordance with the instructions supplied by the manufacturers, and of applying both dusts and sprays at the correct time to avoid (i) upsetting the natural equilibrium between the harmful insect host and its natural enemies, (ii) reducing fruit production by destroying essential pollinators, and (iii) rendering fruit and vegetable crops unpalatable or toxic to man and warm-blooded animals, especially stock.

It is at present desirable to view the introduction of these insecticides as being not far removed from the experimental phase, and to await the results of scientifically planned investigations before recommendations are made on the widest possible scale. In agricultural and horticultural practice, caution is still called for to avoid doing irreparable harm to crops and to those who consume them.

While recognising their respective merits, it may well be that they are but a step, though a long one, towards the development of more potent and effective insecticides in the future.

The inter-relationships that exist between organisms are so complex

that the advent of new insecticides must of necessity be viewed with sane realism. We have at hand insecticides that are more potent than those hitherto developed, and for this reason alone over-exaggerated statements concerning them are harmful to the cause to which we are all committed, namely, the imparting of sound advice in matters pertaining to pest and disease control to those who seek it.

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RECENT DEVELOPMENTS IN INSECTICIDES AND FUNGICIDES PART I

by

HUBERT MARTIN, D.Sc., F.R.I.C.
(Long Ashton Research Station, Bristol)

Insecticides

Chlorinated Hydrocarbons.—The most spectacular advance in insecticides during the war was the discovery of the protective contact insecticide, of which DDT is the first and a most potent example. The early promise shown by this compound as a substitute for derris, supplies of which were short during the war, led to an intense mobilisation of research on its use in medical entomology. As the results of this work on its biological properties and particularly on its chemical and physical properties have a direct bearing on its use as an agricultural insecticide, it is already possible to generalise on the advantages and demerits of DDT as an insecticide.

Among the advantages are, firstly, a high toxicity to insects coupled with harmlessness to warm-blooded animals. True, DDT is poisonous if eaten in a large amount or if persistently applied in a fat solvent to the skin. But neither circumstance need arise in its practical use, though it should be remembered that evidence of its cumulative toxicity in the form of spray residues is still insufficient to permit a final conclusion and care should still be taken to avoid DDT applications to food or fodder crops within a month of harvesting or feeding to stock. A second advantage is that it is possible to compound DDT in a variety of ways so that the sprays, dusts, or mists used are safe to plants. Other advantages are that DDT is virtually odourless and is cheap to make and, finally, that the chemical is remarkably stable when exposed in thin deposits to sunlight, a property shared in only a slight degree by previously known contact insecticides and which enables its use to render foliage and twigs persistently toxic to insects. It is this property of protective contact action to which the high scientific and popular interest in DDT is due. An important exception to this list of advantages is that the cucurbits, including cucumber, melons, etc., appear to be susceptible to injury by DDT itself, and for the time being at least the recommendation of DDT products on such plants should be avoided.

Few if any insects can survive contact with the DDT deposit, even that obtained with sprays containing as little as 1 lb. DDT per 100 gallons. Leaf-eating lepidopterous larvae and insects such as capsids and those

Part I deals with developments up to the middle of 1946. For more recent developments, refer to Part II on pages 143–9.

weevils which spend much of their time wandering over the plant surface succumb to even lower concentrations. Indeed the high toxicity of the deposit may be almost a disadvantage, for care must be taken to avoid the destruction of beneficial insects, i.e. the pollinators and predators.

On insect-pollinated crops the application of a DDT preparation should be avoided within a month before flowering. The danger to predatory insects is especially serious when the pest is little affected by DDT, as are the red spiders. An increase in the infestation of fruit tree red spider is observable even when DDT is applied at bud burst for the control of apple blossom weevil, a stage long before the hatching of the overwintering red spider eggs. This use of DDT therefore requires additional precautions against the red spider. Fortunately in some cases it is found that the beneficial insect is more resistant to DDT than the pest; syrphid (hover fly) larvae are, for example, little affected by DDT deposits at concentrations toxic to the aphides on which they feed.

Benzene Hexachloride.—The second protective contact insecticide for mention is benzene hexachloride, the insecticidal properties of which were guessed at as long ago as 1933 (U.S.P. 2010841). The compound was first tested as an insecticide by Dupire in 1941 in France and, independently, in the I.C.I. laboratories in this country. In the latter work it was found that one particular form of benzene hexachloride is much more insecticidal than others. When benzene hexachloride is made by the chlorination of benzene, a mixture of compounds of formula $C_6H_6Cl_6$ (hence the name '666') is produced. This mixture has been resolved to four isomeric compounds, and of these the gamma-isomer is the most potent. For this particular compound the trade name 'Gammexane' has been registered, but unfortunately this name is widely used for the crude mixture. The latter is better known as benzene hexachloride, for it may well be that the properties of the mixture are different from those of the gamma-isomer. In any case, no suitable commercial method has yet been found for the separation of the gamma-isomer, and all field-scale trials have so far been made with crude benzene hexachloride containing just over 10% of the gamma-isomer. By and large, benzene hexachloride is of the same order of toxicity as DDT, but unlike DDT the compound is slightly volatile, sufficient for it to act as a fumigant yet insufficient to destroy protective insecticidal properties. For this reason benzene hexachloride would seem the better material for use as a soil insecticide, whilst it has been outstanding for the protection of seedlings against flea beetle attack.

Benzene hexachloride has, however, one serious disadvantage upon which work is still far from complete. It appears to be responsible for imparting a noxious taste to food plants on which it has been used. On the Continent, where benzene hexachloride has been under trial for at least three seasons, it is stated that potatoes, the haulm of which was treated with benzene hexachloride against Colorado beetle, developed an unpleasant taste. In this country the report that turnips dusted at the seedling stage with benzene hexachloride had an unwanted taint when

canned is under test. Until disproved it is well to avoid the recommendation of benzene hexachloride insecticides on food crops.

DDT and benzene hexachloride are both chlorinated hydrocarbons, and already a dozen or so of these compounds have been found to be insecticides. Most of them are, however, less effective than DDT as protective contact insecticides and are of greater theoretical than practical interest. Two merit mention; the first, Velsicol 1068—the number indicating its empirical formula $C_{10}H_6Cl_8$—is, to judge from reports of its biological properties (*J. Econ. Ent.*, **38**, 661), intermediate in insecticidal potency between DDT and gamma-benzene hexachloride. The product is again a mixture of isomers, the precise structure of which appears to be unknown. The second insecticide, Synthetic 3956, is stated to be a chlorinated bi-cyclic terpene, and in the first preliminary trials proved more toxic to lice than DDT.

Dinitrocresol (D.N.C.).—During the war the winter wash containing 0·1% dinitro-*ortho*-cresol and 5% high-boiling petroleum oil became popular, though work on its biological properties was at that time incomplete. Among recent discoveries it has been found that the ovicidal properties of the cresol are influenced by the acidity or alkalinity of the spray in which it is applied. Thus against the eggs of fruit tree red spider the cresol at 0·1% will give a 100% kill of the eggs if applied in acid sprays, whereas applied in alkaline sprays the hatching of the eggs are practically unaffected. The reason is that the cresol itself is ovicidal, but the cresylate ion (which is the form present in the alkaline spray) is non-ovicidal. For practical use a fool-proof method of ensuring that D.N.C. is present as the cresol is required, but the difference is of less importance in the case of eggs of aphides, sucker and winter moth, for it does not appear at the concentration of 0·1%. This concentration is the lowest which can be recommended in practice, for even at this strength the kill of eggs of apple sucker is incomplete. Growers who prefer the D.N.C. to the tar oil winter wash should therefore be advised to use a tar oil every fourth or fifth winter in order to avoid the build-up of sucker which might follow continued D.N.C. treatment.

A third point is that D.N.C. is now known to be susceptible to a chemical reaction called reduction, and that the reduction products are not ovicidal. A loss of efficiency thus follows if D.N.C. preparations are exposed to conditions favouring reduction. If sulphite lye is used as the emulsifier the wash should never be made alkaline, because the sugars present act as reducing agents in the presence of alkali. Further, if corrosion of the drums occurs, conditions may become suitable for electrolytic reduction to proceed. Fortunately the reduction products are brownish-black in colour and reduction is accompanied by a colour change from buff or orange to a deep reddish-brown. Discoloured material should accordingly be returned to the maker, who will replace with fresh material.

An even more recent observation is that D.N.C. washes withstand the

effects of rain after application better than the tar oil washes. This observation, not easy to put to large-scale trial, must be checked; but it is of some importance, for it is still necessary that pest control materials should be made as foolproof as possible.

Fungicides

There is no spectacular advance to record in fungicides, perhaps because the old favourites—lime sulphur and Bordeaux mixture—are so effective and cheap. The low initial cost of Bordeaux mixture is, however, offset by the heavy wear it causes on spray machinery, a defect due largely to the grit present in the lime used for its manufacture. There is accordingly room for the more expensive Bordeaux substitute provided it is less hard-wearing on the spray pumps. A convenient group of substitutes are:

Dispersible Copper Powders.—These on addition to water disperse to suspensions suitable for spraying. They contain up to 50% of copper in the form of basic copper sulphate or cuprous oxide together with a dispersing agent such as sulphite lye. These products are worth trial as substitutes for Bordeaux mixture, and are of the same order of efficiency at equal copper content; but naturally they should be recommended only on crop plants on which Bordeaux mixture has been proved safe.

Dispersible Sulphur Powders.—Lime sulphur is, after all, merely a device for applying a fine residue of sulphur to foliage, for on drying the diluted spray decomposes to sulphur. The sulphur residue is extremely tenacious, and attempts to prepare a dispersible sulphur powder have so far failed to give so tenacious a deposit. Consequently the dispersible sulphur powders are less effective than lime sulphur as protective fungicides, a disadvantage sometimes offset in part at least by their greater safety to foliage. Lime sulphur damage is of two types: first the rapid defoliation of the so-called sulphur-shy varieties, for example, *Leveller* among gooseberries, *Stirling Castle* among apples. This damage is caused by sulphur itself and is therefore given by the dispersible sulphur powders. The second type of damage is the stunting and distortion of the leaves, which are usually burnt at the edge; this damage is due to the soluble sulphides present in the diluted lime sulphur, and as there are no soluble sulphides in the dispersible sulphurs the latter should not cause this type of foliage injury. Moreover, the objectionable black sludge of the lime sulphur-lead arsenate spray is lead sulphide caused by the interaction of the arsenate with the soluble sulphides of the lime sulphur. The dispersible sulphur powders thus provide a way of avoiding the sludge of the combined wash, though their wider use is as mild protective fungicides on crop plants tolerant of sulphur.

Organo-Mercury Foliage Fungicides.—An alternative way of dodging the lead sulphide sludge is to use in place of lime sulphur an organo-mercury fungicide. These compounds were developed in Germany primarily as components of seed disinfectants for the treatment of cereals against certain seed-borne diseases. Until recently they have shown little

promise as the basis of protective fungicides for foliage application. In Germany the efforts of the commercial firms making the seed dressings were completely unsuccessful and the attempt was abandoned. In the United States a new series of quaternary ammonium derivatives has been under test, and one, Puratised N5D (stated to contain phenyl mercuric triethanolamine lactate), has given promising control of apple scab, (*Venturia inaequalis*) at mercury concentrations of the order of 1:20,000. In this country the story begins with the observation, at East Malling, that phenyl mercury chloride shows exceptional toxicity to *Venturia* spores. As the compound has the low water solubility required of a protective fungicide, it has been subjected to wide field trial in the following compounded forms: on china clay with suitable dispersing agent, to which form the name 'Venturicide' has been applied; on lead arsenate—'Mercurated Lead Arsenate'; on china clay with DDT added—'Mercurated DDT'. These materials applied at the rate of 1:20,000 phenyl mercury chloride have given a scab control roughly equal to that of lime sulphur, but present evidence suggests that the margin of safety between mercury concentrations giving effective scab control and those causing foliage injury is not large. Mercurated DDT is said to have caused severe injury to Cox's Orange, but the two other preparations seem safe enough for further trial, though their recommendation for use on all varieties in all seasons would be dangerous.

Organic Sulphur Fungicides.—Of the many sulphur compounds tested for fungicidal properties, the most promising so far found are the dithiocarbamates and the thiuram sulphides. These are related, the former of general formula $R_2N.CS.SM$ where R is an alkyl group and M a metal, which in the thiuram sulphides is replaced by a second dithiocarbamate grouping to give $R_2N.SC.(S).S.CS.NR_2$. A systematic examination of the effects of the alkyl group showed that fungicidal efficiency is greater the smaller the alkyl group, and to satisfy solubility requirements ferric dimethyldithiocarbamate was selected for trial. This compound is the effective constituent of the American product Fermate, but to my knowledge no product of this type is yet on the market in this country. One disadvantage of the ferric salt is the unsightly black spray residue which defies removal by wiping, at least when applied to apple fruitlets. In Germany the zinc salt which gives a white deposit has been officially recommended for use against apple scab and also vine downy mildew.

The corresponding thiuram, tetramethyl thiuram disulphide (TMTDS), has been used in this country in a proprietary fungicide and merits trial as a mild fungicide generally unharmful to foliage. In Germany it is also the basis of a product officially recommended for post-blossom use against apple scab.

The Official Approval of Proprietary Insecticides and Fungicides for Use on Plants.—The displacement of the home-made insecticide or fungicide with relatively simple ingredients such as sulphur, lime and copper sulphate by the proprietary product compounded from complicated

chemicals with unwieldy names creates difficulties for the advisory officer. He is, for instance, likely to meet trouble if he recommends a particular product, for he has no means of justifying his selection should he be challenged by the makers of similar but rival products. No practical method of official test for such products has yet been devised—indeed it might not be advantageous to have an official testing scheme. An alternative plan, particulars of which have been published in *Agriculture* (Vol. **50**, p. 331), is now under trial, and the latest list contains the names of nearly 200 approved products.

It should be remembered that approval is based not only on the composition of the product, but that the recommended uses and directions for use are also scrutinised. The product is approved only for these specific uses, and advisers would do well to tabulate not only the names of the products but to study the recommended uses, if they are to gain the greatest help from the scheme. Unfortunately the approval mark is not yet well known because of war-time difficulties which prevented the issue of the approved labels. Nor was it possible to open the scheme at once to all types of products, for which reasons no attempt was made to make the scheme more widely known. Soon, however, the new labels will be appearing and the range of approved products will become large enough for the scheme to receive greater publicity. The help of the adviser in this publicity will go far to make the scheme successful in resolving the difficulties he would otherwise meet in dealing with proprietary pest control products.

THE INCIDENCE OF PLANT DISEASES IN ENGLAND AND WALES

by

W. C. MOORE, M.A.

(Plant Pathology Laboratory, Harpenden, Herts.)

THIS paper is not intended as an annotated catalogue of diseases of horticultural crops or an attempt to place them in order of merit or demerit. I shall try rather to select and comment on some of the more familiar plant diseases, by way of illustrating how the incidence of disease varies from year to year and from district to district, and how it may be or has been influenced, for instance, by weather and soil conditions, by changing cultural practices, by the impress of abnormal war-time conditions, by the application of new knowledge about a disease, and by apathy and failure to apply existing knowledge. To some extent I shall be trying to make bricks without straw, and my remarks should be regarded, not as *ex cathedra* statements but as opinions to be modified, checked and challenged in the light of experience.

Plant Disease Surveys and Disease Measurement

One of the greatest difficulties in assessing the relative prevalence, intensity and economic importance of disease is to get things into true perspective and there are so many pitfalls that it is wellnigh impossible always to maintain a proper balance. Accuracy of diagnosis is the first essential, for without it one can get nowhere. In the aggregate 'blanks' or 'misses' in potato crops, if regarded as the result of a single disease, would rank very high among any grouping of diseases, but they constitute only a 'symptom' which can be induced by one or other of several different diseases (skin spot, dry rot, stem canker, and premature tuber formation among others), and these must be clearly distinguished. The importance and geographical distribution of the crop must also be taken into account, and it is very easy for the pathologist, in concentrating on diseased crops, to forget the usually greater number of healthy ones. Moreover, in reporting on diseases, those that are receiving special attention from research workers are apt to be given undue prominence, and certain old and familiar ones may readily be taken for granted and be forgotten. Again, the balance may easily be upset when a certain disease or group of diseases becomes fashionable or otherwise takes the public's fancy, not least because so many quite different things are then lumped together under the fancied name. Serious and spectacular as stem rot (*Didymella lycopersici* Kleb.) of tomatoes has frequently been in the last few years, in the majority of outbreaks the loss does not exceed 1% to 5% of the plants, and quite

Paper read at the Revision Course in September 1946.

often heavy loss has wrongly been attributed to that disease. When comparing pre-war with war-time and post-war years, due allowance must of course be made for the added attention paid to diseases of crops such as tomato, lettuce and onion which assumed so much greater importance during the war, as well as for the virtual neglect of diseases of ornamental crops in that period.

Planned Surveys and Disease Measurement.—Consideration of all these factors points inevitably to the need for careful surveys and accurate measurement of disease before really reliable conclusions can be drawn about the incidence, and ultimately the economic importance, of disease. Work along these lines is still in its infancy, but reference to some results already obtained may serve to emphasise its significance. In 1943 a special survey of onion diseases was carried out by the Provincial Advisory Mycologists. Crops selected more or less at random were inspected, and the presence or absence of disease was recorded according to a prearranged uniform plan. Altogether 600 acres, or approximately 5% of the total onion acreage that year, were inspected once or twice during the season.

The survey was repeated in 1945 with much the same experience, and as a result it can now be stated confidently that the most important onion diseases are downy mildew (*Peronospora destructor* (Berk.) Casp.), white rot (*Sclerotium cepivorum* Berk.), and, in storage, neck rot (*Botrytis allii* Munn). Moreover, that in years when downy mildew is not generally above normal, at least one-quarter of the onion acreage is attacked by it. I say 'at least' because in 1943, although 25% of all the inspected crops were infected, only 17% of the acreage inspected before the beginning of August showed the disease, whereas 43% of that inspected during August was attacked. In other words, and within limits, the later the inspection the more the disease. Another confident conclusion is that approximately one-sixth of the onion acreage is contaminated with the white rot fungus. Again, in 1943, uniform sampling of some 550 tons of stored onions in different districts revealed that in a year when neck rot was admittedly above normal, one-tenth of the stored crop was lost because of it.

I will quote only one other figure. In November 1942 a random sampling of potato clamps carried out by the Provincial Advisers all over the country showed that blight (*Phytophthora infestans* (Mont.) de Bary) was responsible for an average loss of about 3% of tubers, which on the basis of pre-war acreages and yields means something of the order of 100,000 tons.

In order to carry out this type of work, simple and rapid but reliable standard methods of recording diseases quantitatively in the field are essential. The Plant Pathology Committee of the British Mycological Society has devoted a good deal of attention to this subject during the past five years, and the Committee's preliminary report (Moore, 1943) has given much helpful information.

The Ministry's Intelligence Service.—Although quantitative survey

work has virtually only just begun in earnest here, there is a fund of accumulated information about the seasonal prevalence of diseases in the periodic reports that have been issued by the Ministry of Agriculture since 1917. In May of that year a sub-committee of the Technical Committee of the War-Time Food Production Department was formed to advise the Department on questions relating to pests and diseases. One of its activities was to inaugurate a plant disease survey (and, of course, a plant pest survey) by means of a system of monthly reports, prepared by specially qualified honorary correspondents in all parts of the country. These reports were collated, summarised and published as a Miscellaneous Publication, which proved to be the first of a series of reports issued as Miscellaneous Publications or Bulletins (Min. Agric., 1918–43).

The Ministry's Plant Pathology Laboratory at Harpenden became the co-ordinating centre for this intelligence work, and since the war of 1914–18 most of the information collected about the incidence and severity of crop diseases has been provided by the Provincial Advisory Mycologists, supplemented by occasional reports from a large number of voluntary collaborators in all parts of the country. For instance, the most recent[1] report (Moore, 1943*a*), which covered the ten-year period 1933–42, contained the names of nearly eighty collaborators. From such a wealth of accumulated data a good idea can be obtained of the seasonal prevalence and geographical distribution of crop diseases, and it is not difficult to draw certain broad conclusions about the relative importance of the different diseases as well as about some of the factors that influence their prevalence.

Factors Affecting Incidence

Weather.—Weather plays a predominant part in determining the incidence of many diseases. There is much to be learnt about the precise effect of the individual factors that determine what we call weather, and about the influence of the 'micro-climate' within a crop, but it is often possible to correlate general or combined weather conditions with the incidence of certain diseases.

Potato blight is a good example, and one to which special attention has been given (Wiltshire, 1931; Beaumont, 1931–7). There are 'blight-free' years and 'blight' years and these correspond fairly closely to 'good' and 'bad' or dry and wet summers. Thus, 1921, 1929, 1933–5 and 1940 are remembered as hot dry summers and in those years blight was of little significance as a leaf disease, while in the wet summers of 1926, 1931, 1936, 1942 and 1946 there were severe epidemic attacks on the foliage. A particularly striking correlation was apparent in 1943, when rainfall was superabundant in the south-west and west and deficient in the east and midlands. That year Devon and Cornwall had one of the worst epidemics of blight on record, and the disease was also severe in parts of Wales,

[1] A further report for 1943-6 (*Min. Agric. Fish. Lond.—Bull.* 139 (1948)) has been published since this paper was read in September 1946.

whereas over the rest of the country the attack was late and the spread slow. The incidence of blight on the foliage is normally indicative of the extent of subsequent tuber losses, except that an early and severe leaf epidemic may be followed by surprisingly low tuber losses, while a late leaf epidemic which progresses slowly, as it did in 1941, favours tuber losses on a considerable scale.

The incidence of chocolate spot (*Botrytis cinerea* Fr. and *B. fabae* Sardina) of bean is also closely bound up with weather (Moore, 1944). The conditions necessary for a severe outbreak are winter injury and late frosts (which give rise to dead or weakened tissues on which a big reservoir of *Botrytis* is built up), followed by wet but not too cold periods between April and July (which favour rapid spread). These conditions are met about one year in six, and the worst epidemics in recent years occurred in 1935 and 1944, when severe May frosts were followed by wet weather in June or July.

To mention but a few other examples of a close relation between rainfall and incidence of disease: 1946 once again justified the statement that a wet May means a bad year for apple scab (*Venturia inaequalis* (Cooke) Wint.); blossom wilt (*Sclerotinia laxa* Aderh. & Ruhl.) of apple, plum and cherry passes almost unnoticed except when the blossom period is wet, and then it may be devastating, as it was to *Morello* and other sour cherries in the south-east in 1939. Downy mildews usually do most damage in wet seasons; this applies, for instance, to the one on onion, and downy mildew (*Pseudoperonospora humuli* (Miyabe & Tak.) G. W. Wilson) of hops normally becomes destructive only if the rainfall for both July and August is above normal.

So far the inference would seem to be that most fungus diseases are wet weather diseases, but this is not so with all diseases. The true mildews, or powdery mildews, are generally regarded as predominant in dry years, though I for one would not like to press the point unduly. It is certainly not true of American gooseberry mildew (*Sphaerotheca mors-uvae* (Schw.) Berk.), and 1938, which was an outstanding year for mildews on all crops, was not particularly dry or sunny after the end of April. Many rust fungi, notably antirrhinum rust (*Puccinia antirrhini* Diet. & Holw.), become serious only in hot and sunny seasons, while a dry March seems to be the usual prelude to the epidemics of gooseberry cluster cup rust (*Puccinia pringsheimiana* Kleb.) which occur about one year in six. Watery wound rot (*Pythium ultimum* Trow) is rarely troublesome unless the weather is exceptionally hot at lifting time, and tip burn of lettuce is commonly thought to be associated with periods of hot weather and vigorous growth after a wet spell.

Some non-parasitic troubles are directly induced by certain combinations of weather conditions. Thus, hollow heart and the various forms of second growth in potato tubers are seasonal troubles that attract attention only when rain follows a long dry period in summer. The condition known as premature tuber formation or little potato, in which the seed tuber fails

to form normal green shoots but produces instead a number of small new tubers clustered around it, was much in evidence in 1946 and was common and widespread in 1944. But this happens only when a mild winter, which favours repeated sprout removal before planting, is followed by low soil temperatures after planting.

Locality and Soil.—With a few diseases, epidemics seem to be more or less restricted to certain localities or certain soils. This may be a reflection of local weather or soil conditions, but the possibility that the epidemics are bound up with concentrations of certain crops in particular districts must not be overlooked, and with a soil-borne fungus it may merely mean that some soils are contaminated with the fungus while others are not. Differences in relative humidity probably account for the fact that downy mildew of onions rarely causes appreciable loss in the onion-growing districts of Bedfordshire and Worcestershire, while it is often serious in the coastal regions of the South-east, East Anglia and Lincolnshire. The high humidity occasioned by frequent sea mists in the Isles of Scilly and the extreme south-west of England is sufficient to explain why leaf diseases of Narcissus become epidemic only in these areas; whereas, on the other hand, the distribution of antirrhinum rust seems to be correlated with temperature. After its first appearance in England in July 1933 (Pethybridge, 1934), this rust proved very destructive during the hot summers of 1933–5 in all districts south of a line from the Wash to the Bristol Channel, but it has never become firmly established north of that line and is rare in Scotland.

As is well known club root is worst on soils deficient in lime, and, as might therefore be expected, fewest reports of it come from districts where the soil overlies chalk or limestone. Other instances might be mentioned, but as the correlating factors are less certain or virtually unknown, I will pass on to deal with some of the effects on incidence of disease of the application of fresh knowledge about diseases and of changing practices in cultivation.

Application of Results of Research.—This subject is a wide one, and I can do no more than select a few examples. The first thing that comes to mind is the breeding of resistant or immune varieties, and the most spectacular example is wart disease of potatoes, the economic importance of which has undergone a considerable change during the last 25 years. Its spread was greatly reduced by the operation of the Wart Disease of Potatoes Orders of 1923 and 1929. In the six-year period 1917–22 there were 911 parishes newly infected with wart disease or about 150 a year, while in the 23 years from 1923–45 there were only 278, an average of 12 each year. More important, however, is that plant breeders concentrated on the production of new varieties immune from the disease, and at the present time some two-thirds of the potatoes grown in this country consist of immune varieties. Consequently the disease is no longer the menace that it was.

Again, blotch (*Cercospora melonis* Cooke) of cucumber virtually

wiped out the cucumber crop in North London at the beginning of the century, but following the introduction of the variety Butcher's Disease Resister, which was derived from two unaffected plants in a crop otherwise destroyed on the nursery of Mr. Robert Butcher at Dunstable, Beds., the disease became almost unknown in commercial glasshouses, and is now rarely reported. Modern examples are varieties of tomato, such as Vetomold highly resistant to leaf mould (*Cladosporium fulvum* Cooke) and the new strawberry varieties raised by Mr. R. D. Reid (1941) at Auchincruive, which are very resistant to red core (*Phytophthora fragariae* Hickman) and are serving to put the Lanarkshire strawberry industry back on its feet. The remedy has its own drawbacks, for the parasites may change as well as the host, and constant watch must be kept for new and more virulent strains that attack resistant or immune as well as susceptible varieties.

The practical application of fresh knowledge, however, has a profound effect on incidence of disease quite apart from the introduction of immune or resistant varieties. The introduction of Health Certification Schemes is likely to play an increasingly important part in this, especially as far as virus diseases are concerned. Already there has been a marked improvement in the health of potato stocks following the introduction by the Department of Agriculture for Scotland in 1931, and by the Ministry in 1940, of schemes for certifying growing crops in respect of their freedom from leaf roll and severe mosaic. While the problem is not completely solved, as indicated, for instance, by the exceptional abundance of leaf roll this year (1946), even in some crops from the best certified Scotch and Northern English seed, a big step forward has certainly been taken, and parallel results may be expected in time from the health certification of other crops.

Many other examples could be given, but two must suffice. Before 1930 stored daffodil bulbs suffered badly in this country from basal rot caused by *Fusarium bulbigenum* Cooke & Mass. Research showed that the disease could be avoided and its spread prevented by cool storage, and by adding formalin or some other fungicide to the bath when the bulbs are given hot-water treatment against eelworm (Gregory, 1932; Hawker, 1935). It was largely as a result of the general adoption of these measures that basal rot ceased to be of any real importance in the years immediately before the war.

Twenty years ago the three commonest diseases of gladiolus in imported corms from Holland were dry rot (*Sclerotinia Gladioli* Drayt.), scab (*Bacterium marginatum* McCull.) and hard rot (*Septoria Gladioli* Pass.). About that time complaints were continually made about the health of imported gladiolus corms, and the Dutch Government took active steps to become familiar with the diseases of this crop and to deal with them as they had already done for the diseases of other flower bulbs. It is easy to recognise and rogue out plants affected with dry rot and to deal with scab, but hard rot presents much greater difficulties. It therefore seems to

me highly significant that by 1939 the only one of these three corm rots at all common in Dutch consignments was hard rot.

Cultivation and Cropping.—The effect of changing practices in cultivation may be a purely incidental one. The need for speed in spraying large acreages of apples to control Scab led to the virtual abandonment in the early thirties of the low-pressure, misty type of spray in favour of a driving or drenching spray. This naturally involved a greater risk of spray injury. Bordeaux mixture became largely replaced by the less phytotoxic lime sulphur, and when this practice had become general one of the incidental blessings was a welcome reduction in the amount of mildew, which can be controlled by lime sulphur but not by Bordeaux mixture. During the last year or two, however, there has again been a noticeable increase in mildew, and it has been suggested to me by Mr. M. H. Moore that though this may partly be due to war-time labour shortage, it may well be connected with the increasing popularity of the 'renewal system' of pruning, which leaves behind on the trees many infected buds that would be removed by spur pruning.

The most striking results of changing practices can perhaps best be illustrated by considering the effects of the impress of abnormal war-time conditions. The war brought many new cropping problems and not the least of these was the question of mineral deficiencies, which came into prominence as a result of the ploughing-up programme and general shortage of fertilisers. Before the war deficiency diseases were only of local importance or academic interest. During the war they assumed a great importance, were given considerable attention, and taught us valuable lessons. In future the balance is likely to be restored and we shall be able to get a better perspective of their relative significance among the whole field of plant pathology—for they are and ought to be regarded as an integral part of plant pathology.

The compulsory cropping of glasshouses with food crops immediately increased the risks of disease under continuous cropping with tomatoes. The remedy was to hand and, through demonstration and publicity, soil sterilisation became accepted as an essential operation. The permanent effect of this on the incidence of disease remains to be seen, but it should be substantial. Another effect of the same change has been the noticeable reduction in reports of spotted wilt (virus) of tomato, which before the war was prevalent and sometimes serious on mixed nurseries where ornamentals and tomatoes were grown in the same house.

The enormous expansion of outdoor tomato growing from 230 acres in 1939 to 4600 acres in 1945 has been reflected in the incidence of disease on the crop. Blight (*Phytophthora infestans* (Mont.) de Bary), which is uncommon and usually mild under glass, became a major disease on the outdoor crop, and in 1941, before spraying had become the rule, a severe epidemic rendered many crops useless, especially in southern districts. Fern leaf, due to cucumber mosaic virus, is another disease that became prominent on the outdoor crop and was unusually prevalent in

1944, while in the last three years the so-called early blight, caused by *Alternaria solani* (Ell. & Mart.) Sor. *sensu* Jones & Grout (Glasscock and Ware, 1944), has passed from a disease of doubtful authenticity in this country to one that has already been responsible for widespread epidemics in the south-east and the Isle of Wight.

Among other vegetable diseases mention must be made of the virus diseases of crucifers, which in the last few years have become a menace all over the country, partly if not mainly as a result of intensive and continuous all-the-year-round cropping with brassicas. Parsnip canker has been given brief, but relatively speaking, undue importance. I mention it chiefly as illustrating the paramount need for accurate diagnosis, for there is a tendency to call any and every parsnip trouble 'canker', be it due to weather, eelworm, fungus or fly, and thus to give it an exaggerated importance.

Some diseases have no doubt increased lately because of labour difficulties. Brown rot (*Sclerotinia fructigena* Aderh. & Ruhl.) of apples, for instance, the control of which depends to a large extent on hygienic measures and on the control of insect pests, is getting out of hand, and every year instead of every third or fourth year now seems to be 'a brown rot year'. All this time, of course, diseases of ornamental plants were losing their significance and there is a real danger that as the flower crops return, disease will become a major factor unless proper precautions are taken.

Failure to apply Existing Knowledge.—This leads me on to consider briefly the effects of lack of knowledge and of the failure to apply existing knowledge. There are a number of important diseases which continue to cause heavy loss year after year simply because either the precise cause is unknown or there is no adequate method of dealing with them. Among those that come to mind are the soft rots of brassicas and other vegetables, tip burn and marginal spot of lettuce, bitter pit of apple, root rot of narcissus, chocolate spot of beans, neck rot and white rot of onion, and black spot of rose. In time no doubt remedies will be found for them, just as one may soon be expected for dry rot (*Fusarium caeruleum* (Lib.) Sacc.) of potato now that this disease is being thoroughly investigated.

There is much less excuse for the prevalence of certain diseases for which existing knowledge provides a remedy, but towards which there is a great deal of apathy. Outstanding examples of this are damping-off and foot rot of tomato seedlings caused by species of *Phytophthora*, and blossom end rot of tomato fruits which can be so readily corrected by regular watering. Silver leaf (*Stereum purpureum* (Fr.) Fr.) of plums and cherries would not be the familiar sight it is if the recommendations made by Brooks (1923–31) and his colleagues over 20 years ago were put into effect, and it should not be difficult materially to reduce the incidence of lettuce grey mould (*Botrytis cinerea* Fr.), celery leaf spot (*Septoria apii-graveolentis* Dorogin and *S. apii* Chester), canker of brassicas (*Phoma lingam* (Fr.) Desm.), carnation wilt (*Verticillium cinerescens* Wollenw.), chrysanthemum wilt (*V. dahliae* Kleb.) and certain other diseases, if the recognised control measures were but put into practice.

The Incidence of New Diseases

In conclusion may I say a few words about new diseases. On an average at least six or seven new or newly recognised parasites or diseases are recorded on crop plants every year in England and Wales. Some of these never assume any economic importance, but each of them must be regarded as a potential nuisance.

Not infrequently a newly introduced disease makes great headway during the first few years and then settles down as a not too troublesome native. Among diseases of this nature that created a great stir when they arrived were hollyhock rust (1873), chrysanthemum rust (1897), American gooseberry mildew (1906), downy mildew of hop (1922) and more recently antirrhinum rust (1933).

Sometimes it is years before new diseases flare up. Cucumber blotch was first noticed in 1896, but it did not become destructive until about 1904. Verticillium wilt (*V. albo-atrum* Reinke & Berth. and *V. dahliae* Kleb.) of hops was first seen at Penshurst, Kent, in 1924. Later it was found at various other places in Kent without attracting much notice, but in 1938 it began to increase rapidly in intensity (Keyworth, 1942), and by the end of 1942 was causing very considerable alarm in the Kent Weald and the south-east generally, where 83 outbreaks had by then been confirmed.

At other times, disease epidemics occur in waves at long intervals. A good example of this is asparagus rust, which was a matter of concern in many parts of the country in 1895 and in the Evesham area in 1904–6. It then became quiescent and nothing more was heard of it until the hot summer of 1933. During the last four months of that year substantial attacks were reported from 25 localities in East Anglia and Worcestershire, since when it has been seen on only a few occasions. Another and more topical example is *Didymella* stem rot of tomatoes which occurs both under glass and in the open. It was known in England as long ago as 1885, but it did not become epidemic until early this century. Between 1906 and 1909 it was very destructive in the Lea Valley, but subsequently decreased in virulence, and until 1938, though still about, it was of no great significance. The following year it began to flare up again, and since 1942 it has undoubtedly been a major disease of the crop, though its intensity may occasionally have been over-emphasised owing to the concern felt at the lack of effective control measures. In late August and early September 1945, Dr. I. F. Storey carried out a very careful and valuable local survey of stem rot in Yorkshire, where the disease was then the most severe one affecting tomatoes. He inspected 112 houses on 31 different holdings and estimated the number of plants killed by *Didymella*. The disease was not seen in 25 of the houses. Up to 5% of the plants were killed in 44 houses, 6% to 20% in 25, 21% to 60% in 16, and over 60% in 2 houses. In other words, 62% of the houses were free or showed not more than a 5% kill, 36% gave a 5% to 60% kill and less than 2% gave more than 60% kill. From the detailed figures submitted it is possible to

estimate that approximately 7% of the 300,000 plants involved were actually killed by *Didymella*. To this must, of course, be added a large number of plants that were infected but not killed.

Of the many diseases recently reported for the first time in England and Wales, I would like to mention four of the more important ones.

Bacterial canker of tomato, caused by *Corynebacterium michiganense* (E. F. Sm.) Jensen, was first recognised under glass in Sussex in June 1942 (Ware & Glasscock, 1944). It may have been present here before then, for the disease is not a serious one under glass, but in the last three years it has been responsible for material losses in outdoor crops. Up to the present it has been confirmed in 36 localities, mainly in the south-east and south, the Isle of Wight and the Evesham area, with isolated attacks in Somerset, Essex, Bedfordshire, Lancashire and Northumberland.

Though red core (*Phytophthora fragariae* Hickman) of strawberry had undermined the strawberry industry in Lanarkshire by the early twenties, its presence in England was not suspected until 1931, when it was found in strawberry plants sent to Scotland from Borden in Hampshire. Since then it has been observed in well over 100 fields, mainly in the Westerham Hill district of Kent (Hickman, 1940), the southern part of Hampshire, and the Tamar Valley, but also at one or more widely separated places in Sussex, Somerset, Devon, Worcestershire, Essex, Leicestershire and Cheshire.

I have already referred to three important corm rots of *Gladiolus*: a fourth, caused by one or more species of *Botrytis*, was responsible for a good deal of loss just before the war, and bids fair to become the most serious disease of this crop in the immediate future.

Lastly, there is the downy mildew (*Peronospora antirrhini* Schroet.) of antirrhinum. This fungus has long been known on wild antirrhinums in Europe, but was not seen on the cultivated forms at all until 1936, when it caused heavy loss on a nursery in Eire (Murphy, 1937). The following year it turned up near Brighton (Green, 1938) and in 1940 at Aberystwyth. So far these two are the only known records in England and Wales, but the disease is potentially a very destructive one that deserves more than ordinary attention.

In concluding may I hope that my remarks have indicated that incidence of disease is not entirely at the mercy of wind and weather, and something to be suffered in silence, but is a matter that can be influenced, and influenced very materially, by everyone—whether plant pathologist or not—who is concerned with advisory work in horticultural, or for that matter, agricultural subjects.

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GENETICS APPLIED TO HORTICULTURE

by

M. B. CRANE, F.R.S. V.M.H., A.L.S.

(John Innes Horticultural Institution, London, S.W.19)

In giving an account of the application of genetics to horticulture, not only in respect to the breeding of plants but also in regard to the ways chromosomes and genes directly concern the characters and behaviour of the plants and trees the horticulturist cultivates, it is necessary to refer to some of the older work before one can describe the new. I shall therefore commence this paper by describing the part chromosomes and genes have played, and are continuing to play, in the origin of both species and varieties of cultivated plants and to show how directly they are concerned with variation, productivity, vigour of growth and other essential characters.

Modern methods of research—in this subject a combination of genetics, cytology and chemistry—have clearly shown how many of our cultivated varieties and races of plants have originated and what their ancestors were, and as a result we can conveniently arrange them into four classes according to their method of origin: (1) by selection of gene-mutations; (2) by selection from the products of species-hybridisation; (3) chromosome doubling within the species; and (4) species-hybridisation with chromosome doubling. Of course, selection is much quicker with hybridisation than without it; and with chromosome doubling the new types are often produced at one step—they result from a doubling to the chromosome number by failure of a nuclear division and recent research has shown how this can be brought about at will.

Mutations

I feel there is no need to dwell at length on the part that selection without species-hybridisation has played in the origin of new varieties of horticultural plants as we are all familiar with new varieties which have come about in this way. To take one example, at the beginning of the present century the sweet pea was widely cultivated in this country, but varieties were few and the range of variation limited. Since then not only has the range of colour been greatly extended, but large differences have appeared in habit of growth, structure of leaves and flowers, and as a result the sweet peas grown today are very different to those grown forty or so years ago; and for better or worse the same applies to the tomato, the edible pea, and many other plants. Such new varieties of plants have resulted spontaneously by changes occurring within the plant, i.e. by gene-mutations.

Paper read at the Revision Course in September 1946.

PLATE V (W. A. ROACH)

FIG. 9. LEAF INJECTION BY INTERVEINAL METHOD

Chlorotic Hydrangea leaf: contrast darker green colour of area injected with ferrous sulphate with light yellow of untreated area

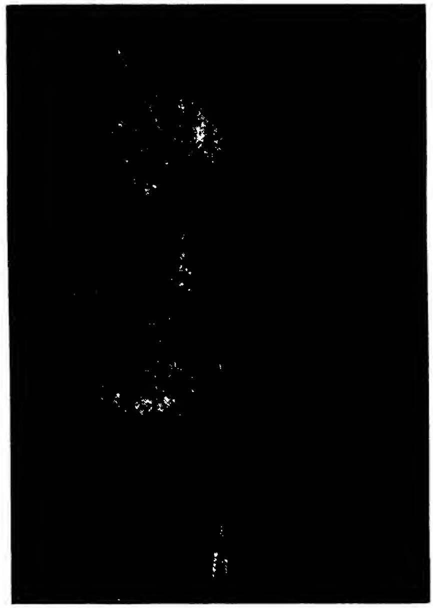

FIG. 10. MIDRIB INJECTION OF LEAF

Manganese-deficient Potato leaf: permeated leaflets on right darker green than the untreated ones on left

FIG. 11. SHOOT INJECTION BY LEAF-STALK METHOD

Chlorotic Peach Shoot: injected with ferrous sulphate between the bottom and 2nd leaves. Bottom side of 2nd leaf nearly normal green; bottom side of 3rd leaf completely cured

FIG. 12. SOLID INJECTION OF BRANCH

Manganese-deficient Cherry branch: left (injected) branch bore dark green leaves and heavy crop; neighbouring right branch bore leaves of a poor colour and hardly a cherry

PLATE VI (M. B. CRANE)

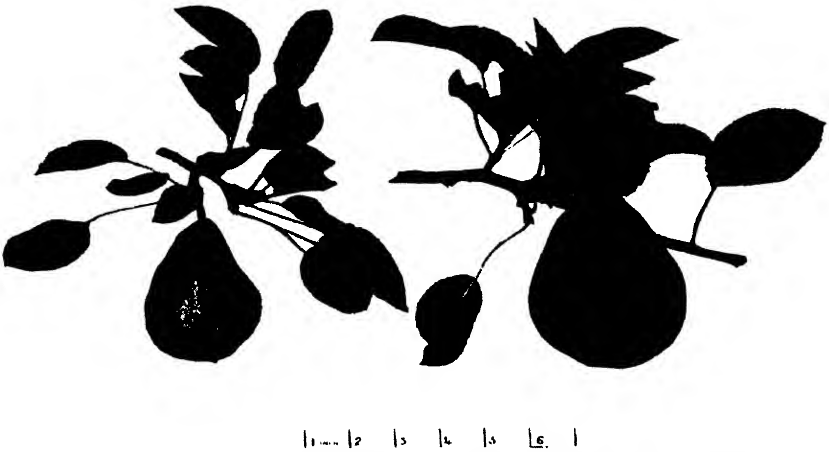

FIG. 13. GIANT PEAR RESULTING FROM CHROMOSOME DOUBLING

Left: Pear variety *Fertility* (diploid 2x = 34)

Right: Its bud-sport *Fertility Improved* (tetraploid 4x = 68)

FIG. 14. GIANT RADISH FROM CHROMOSOME DOUBLING

Left: Diploid *Scarlet Globe* (2x = 18)

Right: Induced tetraploid (4x = 36)

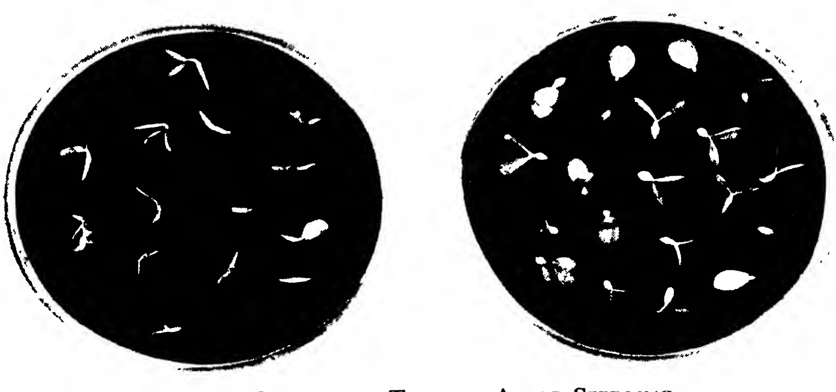

FIG. 15. COLCHICINE TREATED APPLE SEEDLING

Left: Untreated. *Right:* Colchicine treated. Note the treated seedlings have bulbous swellings on the roots which indicate successful treatment

Though often used by horticulturists and plant breeders to produce new varieties by recombination, gene-mutations are not themselves directly due to hybridisation. Nor, as is sometimes supposed, are they due to the direct effects of cultivation, though indirectly cultivation has had important effects (*a*) on account of the close inbreeding involved which reveals mutations latent in the stock; (*b*) on account of selection and/or vegetative reproduction, which maintains these mutations as distinct strains; and (*c*) on account of the protection which cultivation may afford to the less robust types. In a different way, by overcoming geographical and ecological barriers, cultivation has had important results; species distantly separated in nature are brought together and opportunities are thereby provided for hybridisation; this has led to important developments.

Bud Sports and Chimaeras

Gene-mutations have also been responsible for some remarkable plants commonly found in cultivation. Most plants, from the standpoint of genetics and inheritance, are the same all through. Therefore, when they are propagated vegetatively, it does not matter which tissue—stem, root, or tuber—is used to start the new individual, or whether the tissue originates from the inside or outside of the plant. The resulting offspring are always the same, and if they are established varieties they generally reproduce themselves from seed.

But there are surprisingly large numbers of plants which do not possess this uniformity or individuality, and when they are propagated different tissues give rise to different types of offspring. Such plants are composed of two or more genetically distinct tissues and can be classified according to the way in which these different tissues are arranged and grow. In a common type, the so-called periclinal chimaera, one genetic type or variety surrounds another, just as a glove covers a hand.

Most of these plants have arisen by gene-mutations occurring in the body tissues in such a way that only certain layers of the cells which go to make up the plant are affected by the change. Many of these plants can be propagated by root cuttings, and by adopting this and kindred methods their exceptional make-up has been demonstrated, for buds from roots usually arise from the internal tissues. Thus Bateson (1916) found that root cuttings of the pink-flowered *Bouvardia* Bridesmaid produce the red-flowered variety Hogarth. Since then many examples of periclinal chimaeras have been found in a wide range of plants affecting a large number of characters, such as flowers, leaves, spines, fruits and tubers. Many of the so-called bud-sports in flowers and fruits are of this chimaerical structure.

Many varieties of potatoes are periclinal chimaeras, and their chimaerical structure was first demonstrated by Asseyeva in Russia (1927) by a slightly different but equally simple method, viz. by removing the eyes of the tubers and thus stimulating the internal tissues below the excised eyes to form buds. The variety Golden Wonder, which has a thick brown

russet skin, contains internally the variety Langworthy, which has a thin white smooth skin (Crane, 1936), and it is probable that the varieties Up-to-date and Field Marshal, and Great Scot and Sefton Wonder are similarly related. Such plants often present a problem to the plant-breeder, for the external glove-like variety may have a thickness of one or more cell layers. Now the reproductive cells are generally formed from the sub-epidermal or second layer; hence the germ-cells, the egg-cells and the pollen will be of the kind of which this layer is composed. Thus the thick brown russet skin of the potato Golden Wonder is genetically only skin deep; consequently the germ-cells are all Langworthy, and in sexual reproduction the russet character is not passed on and the offspring are all smooth.

Chimaeras of the periclinal type have also arisen spontaneously following the horticultural practice of grafting. They have occurred in this way in apples, roses, medlar, Cytisus and other plants. They have also been deliberately produced by grafting.

Chromosome Doubling

The second mode of origin, a simple doubling of the chromosome number, has yielded, and is continuing to yield a number of new plants. In the Chinese Primula there are varieties with twenty-four chromosomes and others with forty-eight. The latter are giant forms with large flowers, and arose from the twenty-four chromosome forms spontaneously at the beginning of the present century. In pears a new giant form, the first of its kind, recently arose as a bud-sport in the nurseries of Messrs. Seabrook in Essex (Fig. 13). It has twice the usual number of chromosomes, namely sixty-eight instead of thirty-four, and its fruits are of better quality and about twice the size and weight of the variety from which it came (Crane and Thomas, 1939). These are examples of new races of plants which have arisen from a complete duplication of the chromosome number. Sometimes as in *Primula*, they have come about through the sexual process, the germ-cells having a double number of chromosomes; and sometimes, as in the pear, vegetatively, a double number of chromosomes occurring in the somatic or body cells.

Triploids

Many varieties of plants have one and a half times as many chromosomes as their parents and not twice as many as in the new primulas and pears. Thus apples are of two kinds. Some, the diploids, have thirty-four chromosomes (two lots), and others, the triploids, fifty-one chromosomes (three lots). The latter arose from the union of a normal germ-cell with seventeen chromosomes and a germ-cell with a double lot, thirty-four. Many outstanding horticultural varieties of trees, fruits and flowers are triploids with three lots of chromosomes. They are common among plants which are vegetatively reproduced, whether artificially by budding, grafting or cuttings, or naturally, by means of bulbs, corms, tubers and

other methods. Long before their chromosome numbers were known many varieties were unconsciously selected for polyploidy on account of their desirable characters, such as larger size and robustness of growth.

As we have seen, these plants with an increased chromosome number have arisen from the failure of a cell division. In other words they are due to 'accidents' which occasionally occur during the course of reproduction.

Nowadays such accidents can be induced at will. X-rays, extremes of temperature, decapitation and various drugs have all been used for the induction of polyploidy in plants. One of the drugs used for this purpose is colchicine, which is obtained from the autumn crocus. Technically it is not difficult to induce chromosome duplication by the use of this drug. The aim is to double the chromosomes in the cells where growth is active and rapid, such as in a growing-point where cells go on to develop into a new shoot. The best results are therefore obtained by early treatment such as on germinating seeds, young seedlings or young shoots. The usual method is to soak germinating seeds in a weak solution of colchicine 0·05%, or to apply drops to the growing-point of a seedling or young branch. Fig. 13 (left) shows the diploid Fertility pear, and (right) the tetraploid, Improved Fertility, which arose as a bud-sport. Fig. 14 (left) shows the normal diploid radish Scarlet Globe, and (right) tetraploid Scarlet Globe induced by colchicine. Fig. 15 (left) shows untreated, and (right) colchicine-treated apple seedlings with bulbous swellings on the roots which indicate successful treatment. I am indebted to my colleague, Dr. P. T. Thomas, for this photograph.

Species Crosses

The third method by which new plants have arisen is by inter-specific hybridisation. Three species of *Ribes* (*Ribes vulgare*, *R. rubrum* and *R. petraeum*) have entered into the constitution of the garden red currant. Some cultivated varieties strongly favour one or another of these species; others combine the characters of two, such as *rubrum-vulgare* or *petraeum-vulgare*. The species and varieties all have two sets of eight chromosomes. The garden strawberry is an example of the origin of a new race of plants from hybridisation between polyploid species. From all accounts and investigations it is clear that the introduction into Europe, and bringing together of the two octoploid species with eight sets of chromosomes, *Fragaria virginiana* from eastern North America and *F. chiloensis* from South America, provided the first opportunity of raising the large-size fruits characteristic of our modern race. These are also octoploids, and the first varieties of this type, combining the large size of *F. chiloensis* with the aromatic qualities of *F. virginiana*, appeared in Europe towards the end of the eighteenth century.

Amongst the many other genera in which species hybridisation, without chromosome doubling, has given rise to new races of cultivated plants may be mentioned: *Streptocarpus*, *Rhododendron*, *Vitis* and *Iris*.

The fourth and most important way in which new forms have arisen

is by inter-specific hybridisation in which unreduced germ-cells have taken part, or where somatic duplication of the chromosomes has subsequently occurred. This has given us a wealth of outstanding horticultural plants.

The species of *Dahlia* excepting *D. variabilis* are tetraploid, with thirty-two chromosomes, four sets of eight, and they can be divided into two classes: (1) where the anthocyanins are cyanidin types and the flowers magenta; and (2) where the anthocyanins are pelargonidin types and the flowers scarlet or orange. The garden dahlia, *D. variabilis*, combines the pigments of both classes, and has sixty-four, twice as many chromosomes. Combined genetical, cytological and chemical studies carried out by Lawrence and Scott-Moncrieff (1935) convincingly led to the conclusion that *D. variabilis* with its extraordinary wide range of colour, size and form arose from hybridisation between the two types of tetraploid species followed by chromosome duplication.

Breeding experiments and cytological investigations in *Prunus* have led to the conclusion that the diploid species *P. divaricata* with sixteen, and the tetraploid species *P. spinosa* with thirty-two chromosomes are the ancestors of the garden plum, *P. domestica* which has forty-eight (Darlington, 1928–30). In *P. divaricata* the ground colour of the fruits is yellow and the anthocyanin red; in *P. spinosa* they are green and blue, and the range of variation in both species is limited. In *P. domestica*, however, both red and blue colours and also yellow and green grounds occur, and from their various recombinations a very wide range of variation in colour, size, flavour and habit of growth results (Crane and Lawrence, 1938). Normal hybrids between the two ancestral species have twenty-four chromosomes, three sets of eight, and are highly sterile. Such hybrids are still found in forests of North Caucasus. In contrast the plums, with twice as many chromosomes, are highly fertile.

Brassica oleracea—the cabbage, Brussels sprouts and cauliflower group of *Brassica*—has eighteen chromosomes. *B. rapa*, the turnip group, has twenty. The swede (*B. napo-brassica*) and the vigorous kale group (*B. rapa-oleracea*) have thirty-eight (Thomas and Crane, 1942). The latter are composed of double hybrids from the other two—and so, if time permitted, we could go on with this story and show how many more important plants and trees, including our bread-wheats and oats, have originated in a similar way, how they excel their ancestors, and how these occasional 'accidents' in the course of reproduction have bestowed enormous benefits on mankind.

Sterility Problems

The crossing of distantly related plants has been done almost since the discovery of sex in plants in the eighteenth century, in order to bring desirable characters together. In general this is not difficult, but like the *Prunus divaricata* × *spinosa* crosses, the hybrids thus created are usually sterile and hence of little value. In the past we have had to await the rather

rare 'accident' of spontaneous chromosome doubling for the restoration of fertility and the production of desirable new forms.

It is with such sterile species hybrids, rather than with varieties of plants which are already highly fertile, that the induction of polyploidy is likely to prove of the greatest value. As we have seen, polyploidy usually leads to robustness of growth and greater size, but these are not the only advantages; it also increases the range of variation as new genic combinations and hence new forms are obtained, e.g. compare the garden dahlias and garden plums with their ancestral species. It may be felt that I have dwelt too long on the origin of plants, but the more we know of the way they have come about the better we can understand them and the more soundly we can appreciate future possibilities.

We now come to some of the other ways in which chromosomes and genes effect the horticulturists' plants and trees. I feel there is no need to deal at length with the workings of sterilities and incompatibilities in fruit trees (the practical aspects are summarised in John Innes Leaflet No. 4): they are controlled by chromosomes and genes, and if a crop of fruit is to be obtained, it is necessary to follow the fertility rules they dictate, by planting inter-fertile kinds together.

Genetics and Plant Identification

Genetics may be defined, at least from one aspect, as the study of uniformity and variation, of resemblances and differences, and the frequency with which the characters constituting these resemblances and differences appear from generation to generation. Genetics is thus an intimate and exact study of variation and the variability of variation, not only in morphological characters, but also in the chemical and physiological processes of plants. It is upon their behaviour and interactions that genetical conclusions are based, and in conjunction with cytology they often provide reliable means for the determination of relationships, resemblances and differences, which can be directly and confidently used in the classification of plants.

The problems of classification of horticultural crops will, to some extent, differ. In the first place it will differ according to the method of reproduction: whether the plants are asexually reproduced by grafts, layers, cuttings, etc., or sexually from seed. Again some groups and varieties of plants are, of course, more readily classified than others. This is largely dependent on the hereditary behaviour and discontinuity or otherwise of their characters. But even groups such as pears, which long evaded a satisfactory classification, have proved amenable to a worth-while classification, which can be confidently used in varietal identification, when the problem is tackled genetically (Crane and Lewis, 1940).

In clonal crops, all the plants or trees of each variety are simply parts of one individual. On rather rare occasions bud-sports give rise to subclones, and in some crops, such as raspberries and dahlias, we are familiar

with the devastating variation which the inroads of virus leaves in its trail. Environment also has its effects, but apart from these interferences complete uniformity in asexually reproduced crops is the rule.

In crops raised from seed, however, uniformity and hence classification and synonymy has to be viewed from a slightly different angle. Some varieties, usually the naturally self-pollinating inbreeders, are remarkably uniform; but in many crops it is common to find a certain amount of variation within a variety. Such varieties are, however, uniform within a certain circle of variation, and with proper maintenance they conform to a required standard of uniformity. Thus the radish variety *Icicle* breeds true to the colour, shape and other characters of its roots. The flowers, however, may vary; in some plants they may be white, in some lightly tinged, and in others deeply tinged red (Crane and Mather, 1943). In many other vegetables it is common to find varieties pure in respect to their commercial and domestic requirements, but to some extent varying in respect of characters which are horticulturally unimportant. In practice this is all that is required of them; indeed, it is probable that many varieties of vegetable crops benefit from such a degree of heterogeneity and variability, and to attempt to get them genetically pure for unessential characters would be likely to lead to a reduction of vigour and yield, and thus do more harm than good.

Synonyms

This harmless variation within a variety has a direct bearing on the closely 'too much alike' varieties, which are common in horticultural crops. It would, for example, be easy to establish two kinds of *Icicle* radish; one breeding true to white and the other to coloured flowers. It would serve no useful purpose to give them different names, but much of the confusion in horticultural nomenclature is due to the existence of varieties with only slight and unimportant differences.

Apart from 'too much alike' varieties, there is also the question of one variety having more than one or even many names. This is all too common in horticultural crops and leads both to confusion and annoyance; whether it has come about inadvertently or wilfully it is no credit to the horticultural industry, and should be stopped.

There is, of course, one type of small variation which may be justifiable; this is where a strain is selected for particular local conditions, and though it may not differ markedly in appearance it yields better in a particular locality than a related strain brought in from some other part without reference to local adaptation. Such claims with regard to strains appear to be common, but in some cases it is questionable whether the claim has ever been put to a proper test. In any case a little well-directed breeding work carried out in conjunction with properly conducted yield trials would rapidly elucidate and clear up the problems to which synonymy, 'too much alike' varieties, and local strains give rise, and this should be done.

Physiological Grouping

So far I have referred to the classification of morphological differences in plants, but classification according to their chemical and physiological processes are of equal, and indeed often of far greater practical importance. Thus the grouping of fruit trees according to their gene-incompatibility reactions guides the fruit-grower in the lay-out of his plantations, and the classification of Brassica crops according to their chromosome numbers, which in effect groups them according to their origin, fertility relationships and capacity for inter-crossing (Crane and Thomas, 1942–3), shows the seed-grower what kinds he can grow together and what kinds he must keep apart.

To review in detail the different ways by which the high yield and other outstanding qualities of our leading varieties of horticultural crops have been obtained would take a long time, but breeding and selection have played major parts. In most cases, of course, this has only been achieved after many years' work, but in some plants a short cut has been taken to crop improvement.

Hybrid Vigour

When two inbred strains or varieties of plants are crossed together it is common to find that the first hybrid generation is more vigorous than either of its parents. Often this hybrid vigour is accompanied by a higher yield and other economic advantages, and in plants so diverse as maize and forest trees this hybrid vigour has been commercialised with profit and success.

In horticulture hybrid vigour is only just beginning to receive direct attention, but in certain crops it has been unconsciously utilised for centuries. Many of our asexually propagated crop plants have been selected for vigour of growth, high yield, etc., which are to a large extent the result of hybrid vigour. Among such plants are potatoes, apples, pears, strawberries and raspberries. Hybrid vigour in these crops is evident from the fact that they invariably lose much of their vigour when inbred, but the vigour is, of course, maintained in varieties of these crops by the horticultural practice of vegetative propagation; that is, of course, as long as they are free from the inroads of virus and other troubles.

At Merton there is under investigation the utilisation of hybrid vigour in tomatoes, and in some hybrid generations a considerable increase in yield of fruit combined with early maturity has been obtained. Since hybrid vigour is at a maximum in the generation immediately following a cross, the cost of producing cross-fertilised seed by artificial pollination may in some crops render its use unprofitable; in the tomato the production of crossed seed should not be too costly for it to be practised commercially, especially when the small quantity of seed required per acre, and the capital outlay and the cost of growing this crop is taken into account.

Problems of Crop Uniformity

As has been mentioned above, by clonal propagation crops which are

absolutely uniform can be produced; but this method has one inherent weakness which in certain crops has led to serious trouble. It is that if a new disease or pest comes along, to which a particular variety is susceptible, then, since every plant in the clone has the same genic constitution, the whole crop may rapidly suffer. This has happened to varieties of strawberries, raspberries, bananas, dahlias and other crops; in some cases with disastrous consequences. Experiments are being carried out at Merton with raspberries by propagation from seed after systematic crossing to see what degree of uniformity can be obtained. Preliminary results indicate that in this way it will be possible to produce vigorous and high-yielding types of raspberries which will preserve 'surface uniformity', that is to say uniformity in regard to characters of commercial importance, while maintaining some desirable variability in respect of other genes.

In these days of specialisation there is another danger when we concentrate on the cultivation of very few clonal varieties, especially in fruit trees where varieties may be self-sterile or almost so. At best inter-pollinating varieties should be planted regularly and in equal numbers. But the economic advantages of growing and marketing large quantities of a few varieties, rather than smaller quantities of many, has led to the practice of planting comparatively few varieties; often a maximum quantity of one with a smaller quantity of another to serve as a pollinator. I am never happy when consulted about the lay-out of such an orchard. When it is done, special care is necessary in the selection and lay-out of the pollinating variety.

It is important that the variety planted as a pollinator flowers regularly year by year, and at the same time as the main variety. Varieties which are prone to flower and crop abundantly in one year and fail in the next—the so-called biennial bearers—should not be chosen to plant as pollinators. Neither should a variety whose period of flowering only partially overlaps be selected, for as shown by Brown (1940–3) there may be years when they fail to overlap. Recent experiments have shown that given a mass of flowers the area over which bees forage and effectively pollinate a crop is very small. This has led me to conclude that the maximum number of trees of any one variety should not exceed 75%. The remaining 25% should be evenly distributed throughout the orchard (see Text Fig. 3). Cross-incompatibility in plums and cherries is of course now well known and is overcome by planting compatible varieties together. In pears, however, our knowledge is more recent and the occurrence of cross-incompatibility in these fruits does not seem to be so widely known. The pollen of Conference is useless on Beurre d'Amanlis, and all the pollinations so far made between Belle Lucrative, Laxton's Superb, Louise Bonne, Seckle, and Williams' Bon Chretien have failed. It therefore appears that these five varieties form a group within which all pollinations are ineffective.

The space at my disposal has only allowed me to deal very briefly with some of the ways in which genetics concerns horticulture. Although

a very young science it has already provided much fundamental and vital knowledge, and there can be no doubt that the inquiring and efficient horticulturist of the future will be as familiar with the workings of chromosomes and genes within his plants as he now is with the workings of N.P.K. applied without.

M	M	M	M	M	M
P	M	P	M	P	M
M	M	M	M	M	M
M	P	M	P	M	P
M	M	M	M	M	M
P	M	P	M	P	M

Text Fig. 3. Lay-out of Fruit Plantation for Effective Pollination (M = the main variety, and P = the pollinator)

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THE HORMONE CONCEPT IN RELATION TO HORTICULTURE

by
M. A. H. TINCKER, M.A., D.Sc., F.L.S.
(Worplesdon, Surrey)

DURING the last ten or twelve years the rapid development of the branch of plant physiology with which we are here concerned has been remarkable; it is now quite impossible in the space available to review it all adequately, so that this paper can but serve as an introduction to certain general lines of progress, and to practical applications that have arisen from the progress made. Throughout the development of the subject pure and applied science have been intimately co-mingled.

Approximately sixty years ago Sachs outlined the concept of the regulation of physiological reactions, and of growth also, by means of specific chemical substances produced within the plant. In his classical textbook so well known to all, he discusses, for example, the movement through the stem of growth substances, in regard to their function in the regeneration, by rooting, of excised lobes of the stem of *Opuntia*; he there commented upon the rates of such movements in basal and apical directions, and also upon the part such hypothetical substances, as they then were, played in regeneration by means of cuttings of other plants.

Thus, despite the recently made statements to the contrary, the concept is no new one; we can only follow one line of development in broad outline now.

Physiological Investigations

The simple experiment of covering the apical portion of the young shoot of seedling oats with tinfoil, or other material excluding light, often attributed to Darwin, shows that the perception of the stimulus takes place in the tips of the shoot, and when light is excluded no curvature, due to unequal growth on the two sides, results as it does when growth follows the application of unilateral light to uncovered seedlings. Investigations were made to discover the route followed from the perceptive region to the zone of elongation. With an elaborate refined technique, Went in 1928 explored these phenomena, and by excising the apices from the coleoptiles and placing them on agar he was able to isolate from the tissues the responsible active substance that passed downward and controlled growth.

Starling had employed in 1910 the word 'hormone' for such a chemical messenger that was formed in one part of the body and which moved and

This paper was read at the Revision Course in September 1946, and deals with developments up to that time.

controlled reactions elsewhere. So that the word became strictly applicable to the isolated substance Went obtained and reintroduced under controlled conditions to decapitated shoots. Went calibrated and assessed the extracts, he measured biologically the concentration of the substance and explored its great activity. After further biochemical research, Kogl in 1930 reported the elaborate chemical nature of the substance, auxin a, $C_{18}H_{32}O_5$, and of the closely related auxin b. A wide survey was made of plant tissues for a ready source of supply of these substances—grains, maize germs, malt, yeast and other materials were tested.

In urine a third highly active substance was found. This at first was termed heteroauxin, but it was quickly recognised chemically as β-indole-acetic acid. These substances possess activity of a very high order, for 1 milligram (1/28,000 oz.) would be effective in causing curvature in 25,000,000 oat seedlings; the individual seedling must be sensitive to the minutest trace of the substance.

When further plant materials were tested it became apparent that growth hormones were present at varying concentrations in leaves, shoot and other tissues.

Gradually the terms 'hormone' and 'growth substances' were used without implied differentiation, but the occurrence of indolyl-acetic acid within many plant tissues has not been convincingly demonstrated. The relatively simple chemical nature of indolyl-acetic acid quickly led to its application to plants in different ways, and its remarkable activity led to tests of further chemical substances of a somewhat similar chemical composition and structural configuration.

Methods of Application

Lanolin was used in earlier tests as a carrier of the active substances using 1%, 0·1% and 0·01% concentrations when applied to various plants, including young vigorously growing tomatoes. These responded by epinasty of the leaves, curvatures of the stems and unequal rates of growth. (The histological responses need not here now detain us.) Such responses were often obtained within 48 hours after application. From tomato stems treated with such pastes root initials emerged and rows of them might be clearly seen in 10 days or so under favourable conditions. Other test materials included the split stems of sweet peas whose curvature was readily measured. From these and other simple tests it was possible to compare the relative activity of the various chemical compounds brought under review; thus for example phenyl-acetic acid proved less active than indolyl-acetic or its homologue indolyl-butyric, but α-naphthalene-acetic proved highly active. A list of active compounds made in 1935 included those just mentioned and also anthracene-acetic, acenaphthyl-5-acetic, making in all about a dozen. Zimmerman and Wilcoxon in 1935 describe some attempts to correlate physiological activity with chemical constitution and configuration, but these became less successful as the chemical expansion proceeded.

After overcoming difficulties of solubility by means of the sodium or potassium salts and by the use of other solvents, solutions of the active substances were employed. Dusts using talc, pumice and other common dispersion agents have also been employed. A later method of application is by means of aerosols in which the active substance is dispersed under pressure as a fine mist. Here an oil may be used with dichloro-difluoro-methane held under pressure and released at will.

Application to Propagation

Earlier tests were made with lanolin pastes using 1% indolyl-acetic acid. When applied to Doucin apple stocks (XI) some improved rooting of cuttings resulted. Laibach also tried the method of rubbing glycerine, as a potential carrier, into the stems before applying the paste to *Prunus mahaleb* cuttings, or again cuts were made into the stems, as those of *Parrotia persica*, into which the pastes were inserted. Some success resulted from these methods, and Cooper, for example, was able to stimulate cuttings of the Eureka lemon to root by such application of lanolin pastes with traces (1 in 2000) of indolyl-acetic acid.

Solutions were used in various ways for direct uptake by the entire plant or cut portion—by injection into the plant tissues, by sprays on to the parental plant before taking a cutting, and in other ways such as application to the soil in which the plant grew.

When a few c.c. of a solution of a concentration of 100 parts per million of α-naphthalene-acetic are injected into the growing stems of tomato or tobacco or similar rapidly growing plants they induce epinasty, and curvature of the stem, later usually followed by proliferation of the internal tissues and the formation of many roots; when applied to the soil in which such plants grow the chemicals enter the plant and produce very many roots arising over a length of the stem, provided the conditions for growth are suitable in regard to temperature and humidity. Such prolific root formation must needs be controlled for practical purposes, so that many tests of concentration and time of uptake were necessary.

Using a range of between 10 and 100 parts per million of β-indolyl-acetic, indolyl-butyric, α-naphthalene-acetic acid in solutions with periods of uptake of from 12 to 60 hours, followed by washing in water and insertion into a rooting medium such as coarse sand, many workers have tested cuttings from many plants and obtained accelerated rooting, a higher percentage of rooted cuttings, and more roots on the cuttings (Templeman). The nature of the tissue, whether soft or woody, largely determines the concentration proved satisfactory—for herbaceous material 10 to 25 parts per million, for semi-hard wood 30 to 60 parts per million, and for very hard wood 60 to 180 or 200 parts per million—at the highest.

Using the naphthoxy-acetic acids the satisfactory concentrations are much lower: even 2 parts per million may prove effective and the upper limits lie around 25 parts per million for harder materials.

The root systems induced by indolyl-butyric acid are fibrous—they tend to fewer and thicker roots as the result of using a naphthalene-acetic, which may cause a tendency to delay bud growth at higher concentrations. A very large number of plants have been reported to root quite well after treatment. The list includes certain spruces and pines notoriously difficult to root, but other comparable subjects have not responded. Some interesting results have more recently been obtained with lily scales. Dusts and powders have given useful results. Tests have been made by direct application to the parent plant before taking cuttings. A competent review of this work was published by Pearse in the Imperial Agricultural Bureaux series of technical communications.

The aftergrowth of stimulated cuttings may be impaired if the concentration used is too high.

The tissues within the stem, particularly around the outer phloem cells, are stimulated by the chemicals even at a season of normal quiescence. Sections cut in January after December treatment show many new cells arising from rapid cell division, often at the rate of one new layer of cells a day. These cells always give rise to roots; new buds or leaves, usually produced from cells nearer the periphery do not rise; the treatment produces defined results in that way. Root tissues such as those of sea-kale, or Anchusa, are well known to show polarity in regeneration, in that roots emerge from the end farther from the crown and leaves from the end nearer, even if the portion excised be placed upside down; but by a careful study of the distribution of the natural root-forming substance and by applying synthetic substances to reverse the gradient of concentrations it was possible to produce buds at the rooting end and vice versa. (Stoughton and Plant.)

Owing to the tendency of the root-forming substances to retard or inhibit bud development at high rates of application, it appears unlikely that 'bud cuttings'—consisting of leaf blade, petiole and a small shield-shape portion of the stem—carrying an axillary bud will be satisfactory for use by such methods, for immersion of the bud in the solution may result in its retarded growth.

Reverting to the introductory remarks, it is most interesting to read again Sachs' comments on the rate of flow of the growth substances from stem tip towards the base of the stem in the light of the modern work just mentioned.

With a limited number of plants tests have been made with additional aneurin (thiamin chloride) or vitamin B_1. With a few plants better root development followed, but there is insufficient evidence as yet to warrant any recommendation for the general use of this substance for plant propagation.

The stimulation of the growth of entire plants was reported from Canadian experiments made by Grace, who applied small quantities of the active substances tested as dusts; but further work has failed to substantiate these tests and the results of Templeman in 1939, the writer,

and others, have shown that the total growth as estimated by dry weight and in other ways is not increased by their application. No stimulation occurred, but toxic effects developed at higher concentrations. Similarly no stimulation of dormant hard seeds was obtained in the experiments made by Youden, Barton and other workers, so that these substances remain primarily as root-forming substances and regulators of other *specific processes* to be discussed later, rather than as general stimulants.

Some Chemical Considerations

It may be convenient here to consider some chemical aspects and so maintain the general chronological order in this survey. The very close chemical relationship between indolyl-propionic acid and tryptophan led to exploration of the possible relationships between growth substances and amino acids. Parallel de-amination of tyrosine and histamine did not yield active substances as might have been reasonably expected. The occurrence of the indolyl groups as a possible basis for the formation of the growth substance, in those tissues in which it does occur, remains partially unexplained; and the tryptophan-growth-substance relation is perhaps unique. In regard to the indolyl derivates it is interesting to note that the thio-substitution compound shows less activity, whilst iso-indolinone proved inactive; scatole, however, proved fairly active—a point of interest in that scatole occurs in manures derived from faeces. Small quantities of active substances have also been detected in sewage and other organic manures (Hamence). Possibly these manures might encourage root formation in this way.

The next important chemical advance was the reported activity of the phenoxy-acetic and similar acids; their high degree of activity was explored in the early years of the war, to be followed in 1944 by a further expansion which included the xylene-oxyacetic acids (Zimmerman, Hitchcock, *et alia*). Within the phenoxy-acetic acids a wide range of halogen substitution products have now been tested. There were many interesting points showing relationships between chemical constitution and physiological activity, as judged by root formation of a standard test plant, *Euonymus*. All such relationships cannot now be even mentioned, but the kind of, number of, and position taken up by, the substituting elements or groups, as well as the length of the side chains, influenced the resulting activity. When compared with previously tested substances used as well-known standards, the 2-4-dichloro-phenoxyacetic had a greater activity than indolyl-butyric acid for example, or than α-naphthalene-acetic. This can be illustrated by remarking that the new substances require dilution to around 1 part per million for propagation purposes, whereas the older ones give better results at about 50 parts per million. Phenoxy-acetic itself was not so highly active as the chloro-substituted compounds. Homologues like phenoxy-propionic and butyric proved highly active. The xylene-oxyacetic acids also displayed a range of activity according to the substitutions carried out into them.

With naphthalene-acetic additional hydrogen to give the dihydro and tetra-hydro series did not produce remarkable differences, but with tetra-hydro-naphthylidene-acetic acid an interesting point arose, for of the two stereo-isomerides of this compound, one (higher m.pt.) was of great activity (Tincker). Such is the complexity and delicacy of the relationship between the structure and activity.

Other Responses and Applications

With the vastly wider range of chemicals at our disposal, other applications and responses can now be briefly considered.

When, for example, young Cleome plants were exposed (by Zimmerman) to the vapour of ethyl-2-4-di-methylxyleneoxyacetic acid, leaves subsequently developed by the growing plant were greatly modified in form and structure. Other symptoms so induced were similar to those seen in many plants and known to be caused by virus disease, leaf mottling and clarity of the veins. Similarly, with tomatoes the entire series of inflorescences were greatly modified by tri-iodobenzoic acid applied either direct to the plant or to the soil in which it grew. In this case also the correlation of the plant organs was considerably modified, buds reasonably expected to produce vegetative growth gave rise to flowers, and the main shoot was unusual. Now these observations were made as the plant grew—some considerable time after the chemical was taken up. The formative effects were delayed, the action was systemic. Here the degree of stability of the strange chemicals introduced into the tissues may be considerable, but their action in gradually controlling development runs parallel with that of natural hormones in some respects.

Parthenocarpy

Some ten years ago Gustafson showed that in the Cucurbitaceae fruit development may be caused by the application of indole-butyric acid to the style, without the occurrence of normal pollination and subsequent fertilisation. With Crooked Neck Squash, for example, the fruits did not attain the full size of those containing fertilised seeds, but were larger than untreated and unpollinated ones. With strawberries to which a 0·01% solution of indolyl-butyric acid was applied one large fruit per cluster developed (Gardner and Marth); using a mixture of active substances larger aggregate fruits have been obtained with blackberries (Marth and Meader). With grapes attempts have been made in America and at Wisley to make fruits develop to the full natural size without fertilised seeds. These have not been successful, though possibly the application—a wide range of concentrations of napthoxy-acetic was used—may accelerate slightly the ripening of the smaller seedless fruits. American attempts to improve the yield of green-pod snap beans have also been disappointing. Thus plants vary in their readiness to respond, but responsive plants are found in Cucurbitaceae, Solanaceae and Rosaceae.

The most important practical application to date is concerned with

tomatoes. Following the work of Howlett in America, of Swarbrick at Long Ashton and others, many tests have been made with various growth substances. Without pollination fruit development may be readily induced and the resulting fruits are seedless and possess a slightly different internal structure, but their taste and nutritional properties are generally considered to be as good as those of normal fruits. Naphthalene-acetic acid is not used for this purpose. If used at 50 parts per million or higher concentrations dichlorophenoxy-acetic acid may induce symptoms similar to those caused by virus infection and causes other damage at high concentrations; at low concentrations around 5 parts per million some tendency towards rather hollow fruits has been observed, in which the cavity between the tissues of the fruit wall and the placenta is too large. Swarbrick observed large cavities with the dichloronaphthoxy-acetic. β-naphthoxy-acetic acid has generally given satisfactory results at 40 parts per million or so, and has proved of value in obtaining fruits from the earlier trusses with which some difficulty is sometimes experienced. It is pertinent to point out that plant growth substances, tested by Ludford, do not cause cell division and proliferation of animal tissues, so that there does not appear to be any serious likelihood of deleterious results from eating such fruits. After development of the fruits the quantity taken up when eaten must be exceedingly small. In time of application there is a fairly wide range, for fruit development can be influenced to a certain but smaller extent even if pollination has taken place. Stimulation can occur some days after removal of the anthers. Whilst not always necessary, by any means, these substances are useful aids to ensuring an early crop from the first-formed flowers.

Pre-harvest Fruit Drop

The application of certain growth substances, particularly α-naphthalene-acetic acid, to the pedicels of fruits such as apples and pears may delay or inhibit the formation of the abscissional layer so that the fruits remain on the tree longer. It will readily be appreciated that the spray must come into contact with the fruit stalks to ensure rapid effect, and that 'spreaders' may be required. In 1939 Gardner, Marth and Betjer reported their tests made with well-known American apple varieties; later, in 1945, Swarbrick reported tests with selected varieties of English apples. A few months ago Vyvyan published an account of the East Malling experiments made on five varieties of apples, Beauty of Bath, Miller's Seedling, Worcester Pearmain, Cox's Orange and Bramley Seedling, and also on Conference pear. He recommends using 10 parts per million of α-naphthalene-acetic acid for this purpose, applied as a thorough spraying about 10 days or even a month before the normal picking date. His results show a higher degree of effective control obtained with the naturally early Beauty of Bath, always apt to drop its fruits, than with Cox's Orange or Bramley's Seedling. From Norway correspondence shows certain growers there are particularly interested in this matter and

(*Courtesy of Sigmund Pumps*)

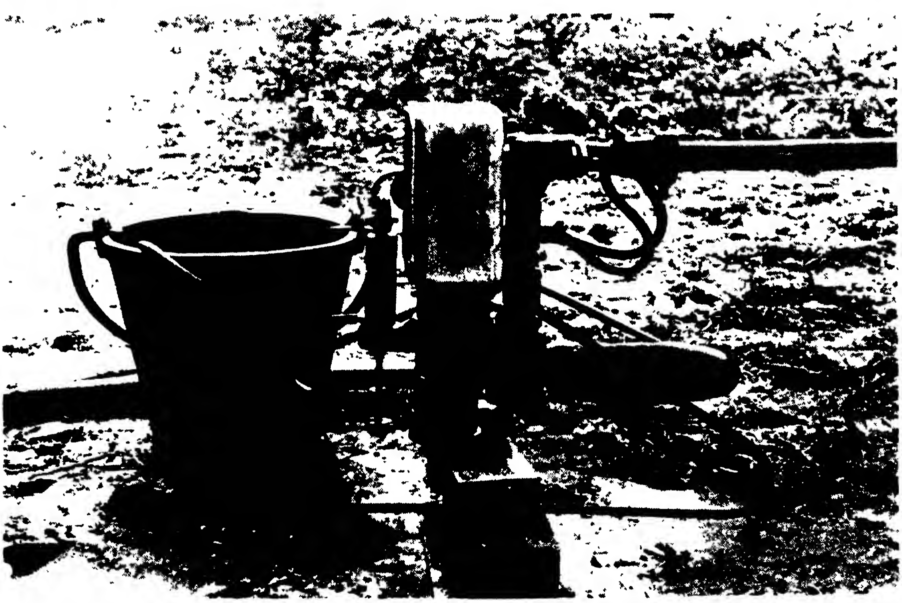
FIG. 16. ROTARY RAINER SHOWING EVEN SPRAY DISTRIBUTION

(*Courtesy of Sigmund Pumps*)

FIG. 17. ROTARY RAINERS OPERATING FROM PORTABLE MAINS

(Courtesy of Sigmund Pumps)

FIG. 18. ROTARY RAINER IRRIGATING CUCUMBERS UNDER CLOCHES



(Courtesy of C. P. Kinnell & Co.)

FIG. 19. OSCILLATOR WITH BUCKET-FED SOLUTIONISER ON SPRAYLINE

only time and further experience will show the value of such sprays in wind-swept areas, but Swarbrick showed in his earlier tests in 1941 that on treated trees the fruit withstood the force of very strong winds without falling.

Storage problems naturally arise, for the development of the fruits is not checked whilst they remain on the tree, and the state of the fruits at harvest influences the keeping qualities. Gerhardt and Allemendinger have inquired into these matters with apples, pears and cherries. In regard to frost damage the artificially enforced retention on the trees of young fruits in which probably only limited fertilisation has taken place, may prove of value as a small crop may result from the incomplete development of these fruits (Swarbrick). Can other methods of application of such substances be used effectively to combat frost?

Delay or Inhibition of Bud Growth

If a cutting of *Viburnum opulus* be taken in early spring and greased with lanolin carrying 1% α-naphthalene-acetic acid, the resulting delay in the opening of the buds may readily be seen. This phenomenon has practical bearings. Is it possible so to delay the opening of flowers, or vegetative buds, as to escape frost damage? In America, Hitchcock made tests with cherries using the potassium salt of α-naphthalene-acetic acid. When applied in July using 200 parts per million on the Montmorency cherry, he observed a subsequent delay of 7 to 14 days in the time of bud opening. He also reported the effective influence of sprays of the dichloro- and trichloro-phenoxy-acetic acids. The problem is complicated in fruits, in which the flower-buds for next season are laid down in the summer before the current season's fruit is harvested. Hitchcock's work showed that application before the buds entered the winter rest period was effective, but there remains the question of causing other effects to the current season's growth. Using the apple variety Arthur Turner, tests were made at Wisley in December, January and February with concentrations of 75 parts per million and 150 parts per million of α-naphthalene-acetic acid applied at heavy rates of spraying. These all proved ineffective in delaying to a material degree the opening of the flower-buds, so that there does not appear to be much likelihood of delaying the bud development by *late* spraying.

The question of retarding buds is of importance in regard to potato storage. Guthrie and Denny have reported satisfactory control of sprouting by the use of naphthalene-acetic acid and its esters, of which the methyl ester vapour was decidedly useful. At Wisley tests were carried out with dusts, powders and sprays carrying the active substance in oils, and with peat and paper as a carrier of the methyl ester. Within confined spaces small samples brought under the influence of the vapour of methyl-α-naphthalene-acetate were prevented from sprouting. The importance of the temperature conditions was observed, and tests designed to give a second season's confirmatory results with the varieties previously

used served only to show that the condition of the test material in different years was another factor, for less successful results were obtained from the same treatment in a second year. Later in the war years the matter was taken up by Crook, Watson, Wilson and Boyd, working as a team to study the reaction of small samples and to investigate the changing conditions within commercial clamps of potatoes. Whilst inhibition of sprouting could be obtained in small samples, there were many obstacles and difficulties preventing the application of these methods to farm practice. Since their report appeared, some further encouraging reports have been obtained from the Continent, so that hopes of prolonged storage have been raised again. Effective control for small-scale work lies in the region of 33 to 100 mgm. of the ester of naphthalene-acetic acid per kilogram of potato. There are other plant tissues such as corms and other tubers which it may be desired to store for lengthened periods, and methods and rates of application will require detailed experimentation.

Selective Weed Killers

The toxic effect of fairly high concentrations of the substituted phenoxy-acetic acids was explored in this country by Templeman, and methods and rates of application worked out for arable weeds. Evidence of the wide range of selectivity of weed killers containing the dichloro-phenoxy-acetic or a methylchloro derivative was rapidly forthcoming, for whereas young cereals are resistant young charlock may readily be killed. The effective rates of application of the active substance, usually dispersed with a carrier at the rate of 1 lb. per cwt. carrier, are very small around 1, 2 or 3 lb. per acre.

As Professor Blackman's paper (printed on p. 117) deals with this subject primarily from an agricultural point of view, it is here only necessary to refer to the published report in the *Journal of the Royal Horticultural Society* for details of the garden tests. The main point of interest is the value of such weed killers on lawns where Cat's ear, Mouse-eared Hawkweed, daisies and dandelions may be killed without injury to the grass.[1] The Wisley tests have also shown that *Equisetum* may be seriously damaged by one application of the weed killer. In the vegetable garden young Brassica plants are very readily injured. Damage may also occur to shrubs.

Future Possible Developments

The physiological investigations that have been carried out, particularly in America and Russia, to elucidate the phenomena of photo-periodism generally tend to support the view that the flowering of short-lived plants may be at least partially governed and controlled by a hormonal mechanism. The investigations with *Xanthium*, the cocklebur, made by Hamner, have made considerable progress in this direction, but as yet no successful

[1] For most recent work on lawn weeds, see R. B. Dawson's article on pp. 150–60. *Editor—S.H.*

isolation of the 'florigen' has been reported. Cajlachjan in his book develops the idea of the hormonal control of flowering; perhaps the future horticulturist will be able to handle the active substance effectively!

In conclusion, I am reminded by the progress that has been made by plant physiologists exploring the natural processes and by horticulturists using synthetic substances to assist in the control of natural processes in their industry, of some words of the late Sir Wm. Pope, a Fellow of my own College and my teacher, when he stated that, "Experimentation on the grandest of scales, by splendidly co-ordinated team work is required so that the infinite number of organic substances that the research chemist has placed at the disposal of man can be put to the proper service of mankind and industry". In practice we cannot test them all in turn; we proceed along the lines illustrated by the auxin work—physiological recognition, isolation and reintroduction, followed by rapid chemical expansion and the very necessary practical tests before widespread application to our industry takes place.

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SELECTIVE WEED CONTROL IN HORTICULTURE

by

Professor G. E. BLACKMAN, M.A.

(Department of Agriculture, Oxford)

THE year 1946 was the half-century mark since the possibilities of selective weed control by chemical means were first explored. The crop was oats, the weed was yellow charlock, the material was copper sulphate, and the discovery was made by Bonnet working in 1896. By 1898 the same discovery had been made in Germany and in America; yet in spite of these independent investigations in three different countries, the subsequent advances which could normally be expected in this then new field did not take place. It is indeed curious that there was so little progress, because much attention was being given to the development of new fungicides, insecticides and bactericides during the '90's and the first three decades of this century. In this period of 'bottle off the shelf' research much time, brains and money were involved in testing new compounds as fast as they were synthesised—but not for their weed-killing properties.

For example, once copper sulphate had been discovered, the next obvious step would have been to test out other copper compounds to discover whether they were less or more active, but nobody, in fact, did so for the next 45 years. It was not until the present war focused new attention on to the problem of weed control that there was a systematic comparison of copper compounds.

After copper sulphate was discovered in 1896, it was followed at short intervals by other compounds such as ferrous sulphate, ammonium sulphate, kainit, etc. These more or less held the fort, at least in England, for the next 30 years, because they were cheap and not corrosive; but they had their drawbacks. They killed only a few kinds of common annual weeds and required good weather to do so. In 1911 came sulphuric acid, again a French contribution since the technique was perfected by Rabaté (1). By 1930 some 500,000 acres of cereals in France were being treated annually with sulphuric acid, yet the initiation of research in this country did not take place until the 1930's (2, 3, 4). Then the trials confirmed the French evidence that sulphuric acid not only killed a wide range of weeds but that it was also more or less independent of weather conditions—an hour's fine weather being sufficient for effective killing. The position in England before the war remained unchanged, for sulphuric acid was still the principal herbicide used for weed destruction, but its employment was confined to destroying annual weed in cereal crops.

This paper was read at the Revision Course in September 1946, and deals with development up to that time.

To maintain the historical sequence one must go back a few years—first to 1932. Then yet another team of French investigators—Trouffaut and Pastac—patented the use of nitrophenols and nitrocresol compounds for selective weed control in cereals (5). Dinitro-ortho-cresol was not a new substance, for it was first synthesised in 1866. It is a bright yellow compound, still being used as a dyestuff today. It was at one time employed for colouring synthetic liqueurs and as a 'slimming salt', but excessive doses taken by over-anxious slimmers led to their 'fading away', like the proverbial old soldier. In consequence the medical practice of prescribing dinitro-ortho-cresol for slimming was given up! Dinitro-ortho-cresol is toxic to human beings because, like the hormones in thyroid extract, it increases the general metabolic rate; but we have yet to learn how it works in plants, and why the action is selective. In this connection it is of interest to learn that in America nearly fifty years ago it was found that D.N.O.C. killed insects *and* the leaves of apple trees. It was this phytocidal action that held up its use as an insecticide until the method of applying it as a winter wash was perfected nearly forty years later.

So far I have discussed sulphuric acid, D.N.O.C., and the alternative copper compounds. Now we come to the fourth development, and this is perhaps the most important of all—the development of selectively toxic growth-promoting substances. Templeman, while investigating the effects of growth substances, such as alpha-naphthyl-acetic acid, used for making cuttings root faster, sprayed oats growing in pots with dilute solutions and noted that while the oats were undamaged, chance charlock plants present were killed. He realised at once that here was a new class of selective herbicide. In consequence a search for more active compounds was at once instituted by Slade. Templeman and Sexton, and a large number were tested out in pot and laboratory tests (6, 7). Finally the methyl-chlor and dichlor derivatives of phenoxyacetic acid were selected as most promising. Curiously enough precisely the same conclusions as to the possibilities of the dichlor derivative (D.C.P.A.) for selective weed control were being made simultaneously by Nutman, Thornton and Quastel (8).

Selective Weed Control

The next link in the chain of development was to compare these compounds (M.C.P.A. and D.C.P.A.) against D.N.O.C., copper salts and sulphuric acid, not only in their effects on weeds but also in their effects on crops. Our comparative trials of the last four years have revealed how complex is the relationship between the weed, the crop and any herbicide. In fact the situation is so complex that it is not yet possible, without actual test, to prognosticate the effect. This complexity is well illustrated by the data presented in tabular form in my article in *Agriculture* (April 1946) (9).

To recapitulate briefly some of the major differences in the reactions of the commoner annual weeds, some weeds like yellow charlock or penny-

cress are effectively destroyed by all these compounds, others such as corn marigold or corn buttercup by only one compound. Even then, individual weed species require different compounds: D.N.O.C. for corn marigold and M.C.P.A. or D.C.P.A. for corn buttercup. Nevertheless, in spite of this general contrariness, the main effects of the four groups of compounds on some thirty-five annual weeds have been established.

So far as crops are concerned, selective weed control has as its object the using of concentrations which kill the weeds but do not kill the crops. A so-called resistant weed therefore is a weed for which concentrations in excess of the limit for the crop must be employed to kill it. Thus goose-grass can be classed as 'susceptible' in cereals but 'resistant' in flax, because sulphuric acid—the most effective spray—does not damage cereals but injures flax (10). In horticulture the normal weed population is far more mixed than in arable farming; in consequence it is necessary on many occasions to use only those sprays which kill a wide range of weeds. For example, copper chloride kills more kinds of annual weeds than copper sulphate, but sulphuric acid destroys even more weed species. This diversity of the weed population in horticulture has so far limited the development of weed control by chemical means. It should be stressed, however, that during the last few years most attention has been given to destroying annual weeds in cereals, flax, linseed and grasses for seed production.

Pre-emergence Spraying

There have, however, been two exceptions: the use of sulphuric acid for weed control in onions and leeks, and the technique of pre-emergence spraying (11). In onions and leeks, sulphuric acid gives excellent results as long as the weeds are small at the time of treatment. Many growers hold that the most important aspect of weed control in onions is to ensure a pre-emergence spraying of the seed-bed—that is to spray the seed-bed just before the onion seedlings emerge, so as to kill the weed seedlings which have come through first. Normally the second crop of weeds appears when the onions have reached the two-leaf stage. Spraying once the onions have 'straightened up' should not be delayed, for many kinds of weeds, when they have passed the cotyledon stage, become considerably more resistant—knotgrass for example. In a weedy crop and in a wet season, a third spraying of onions is possible in the 4–6-leaf stage.

Yield trials have shown that with the recommended concentrations of acid (8 to 13 gallons of B.O.V. acid per 100 gallons) a single spraying of the crop causes no check and a double spraying a very slight one, the check being only marked in poor crops. Leeks can be sprayed in the seed-bed like onions, but in the field spraying must take place within a month of setting out.

The reason why sulphuric acid can be used for a pre-emergence spray is because it leaves no toxic residues in the soil; except in very acid soils the acid combines with the calcium to form insoluble calcium sulphate in the

surface layers. On the other hand D.N.O.C. compounds, M.C.P.A. and D.C.P.A. leave toxic residues. The time that the residues last depends on the weather and the compound. It would appear that in moist warm soils D.N.O.C. compounds are destroyed within a fortnight but D.C.P.A. and M.C.P.A. persist for more than a month. Under dry conditions the periods may be much longer. In fact for all horticultural crops when it comes to pre-emergence spraying, these compounds must be ruled out. Copper chloride can also be employed for pre-emergence spraying as again there are no toxic residues, but its use is confined to fields where the weeds in question are susceptible to this spray.

Apart from onions and leeks, there are so far no other crops for which a technique of selective weed control in the growing crop has been perfected. On the other hand pre-emergence spraying has been extended to include onions, leeks, parsnips, spring-sown carrots, round beet, or any crop where the weeds come up first.

Market Garden Problems

The main hindrance to the development of D.N.O.C. compounds or D.C.P.A. and M.C.P.A. in market gardening is that they are toxic to tomatoes, onions, leeks, parsnips, carrots, spinach, root crops such as beet, the legumes like peas and beans and the cabbage family. In fact, some of these crops are so susceptible that on farms where arable crops and market-garden crops are both grown, great care must be taken to ensure that the spray or dust particles do not drift on to neighbouring susceptible crops. As yet, the reaction of every vegetable crop to all these compounds has not been fully worked out. So for the present, all crops for which no information is available should be regarded as susceptible.

The growth-promoting substances have the unusual feature that they can act either through absorption by the root or by the shoot. In consequence they can be applied as dusts, and it follows as a further corollary that their effect is relatively independent of the weather, though their action appears to be quicker in warm weather and when the soil is moist. There is the additional proviso that if the material is only taken up by the roots—i.e. when rain washes the material into the soil soon after spraying—then *at least* double the quantities are required per acre to give the same degree of control. From this aspect, therefore, spraying is better than dusting since penetration into the shoot is more rapid.

Another distinctive characteristic of these growth substances is that they offer a new means of controlling some perennial weeds which have been difficult or impossible to kill with the older herbicides such as sodium chlorate or sodium arsenite. Moreover these compounds are more selective in their action and so can be employed for the *selective* control of perennials.

Weed Control in Lawns

As experiments on perennial weeds take longer than investigations on annual weeds, the information to date is less precise and so final

recommendations cannot be made in many instances.[1] However, for the control of several common weeds of lawn and sports turf good results have been obtained. It would appear that two to three applications of M.C.P.A. or D.C.P.A., each at the rate of 1½ lb. per acre, are the most effective as long as the applications are made at monthly intervals, starting preferably at the end of April. Such a combined treatment should destroy plantains (*Plantago lanceolata*, *P. media*), buttercups (*Ranunculus repens*, *R. acris*), dandelions (*Taraxacum officinale*), cat's ear (*Hypochaeris radicata*) and greatly reduce if not completely suppress the clovers (*Trifolium repens*, *T. dubium*), trefoil (*Medicago lupulina*), and daisies (*Bellis perennis*). On the other hand Yarrow (*Achillia millefolium*), bulbous buttercup (*Ranunculus bulbosus*), sheep's sorrel (*Rumex acetosella*) are difficult to kill. According to trials in America mouse-eared chickweed (*Cerastium vulgare*) and thyme-leaved speedwell (*Veronica serpyllifolia*) are also susceptible but the results have been variable.

After applying the spray, the turf should not be cut for a few days and a *fine* day should be chosen for the application. The effect on some of the weeds will be very slow and there may be an interval of more than a month before their death. At the rate of application recommended, no damage has been observed to *established* swards. Newly sown lawn should *not*, however, be treated in this way as seedling grasses are less resistant.

In gardens, it may be more convenient to apply the growth substances as dilute solutions with a watering-can. If this course is adopted, the can must be meticulously cleaned out afterwards because it is already known that many garden plants, such as hollyhocks, irises, etc. are killed by these herbicides. Similarly great care should be taken not to let the spray fall or drift on to the adjoining flower-beds.

Finally it seems that some trees and shrubs, more particularly deciduous species, are also susceptible (12). Areas, therefore, in the lawn where tree or shrub roots run underneath should not be treated. At the present stage of knowledge concerning garden plants, discretion is the better part of valour when using these new materials.

What of the Future?

So far I have discussed the past and the present—but what of the future? It is certain that there are bound to be many developments, some of them a long way ahead, and some much closer to hand.

The results of the first trials point to a means of selectively destroying perennial weeds growing in commercial asparagus beds with the phenoxy-acetic acid derivatives. By delaying spraying until the 'fern' is tall but still not tall enough to prevent an operator with a knapsack sprayer going down between the beds, up to a 75% kill of creeping thistle (*Cirsium arvense*) has been achieved, together with a 87% to 95% destruction of

[1] For most recent work on lawn weeds, see R. B. Dawson's article on pp. 150-60. *Editor—S.H.*

bindweed (*Convolvulus arvensis*) with M.C.P.A. and D.C.P.A. The precise time to spray and the correct concentrations have yet to be confirmed. It is, however, certain that unless the bindweed is left until the flower-buds are formed or the plants are in flower, wholly ineffective results will be obtained. As long as the spray only comes in contact with the base of the asparagus shoots, there appears to be no adverse effect on shoot development in the following year.

The other pointer is for the control of annual weeds in umbelliferous crops, such as carrots or parsnips. Eight years ago, it was found that spraying with light mineral oils killed a number of the weeds prevalent in American cranberry bogs without injuring the cranberries (13). Then in California and Australia it was discovered that carrots were likewise resistant to this oil spraying while the weeds were not. Our subsequent investigations in England have shown that the type of oil is extremely important. Some oils kill the weeds and the carrots, some kill neither the weeds nor the carrots, while others are truly selective. What had yet to be learnt is the cause of this variability, and until a specification for the composition of the oil can be drawn up, such a technique remains a probable but not a possible means of weed control.

In conclusion it is clear that important advances have recently been made in evolving new means of destroying weeds. The impetus of these discoveries will lead on to fresh ones and some of these will undoubtedly affect future horticultural practice. How great will be the effects, it is impossible as yet to say for all the past discoveries in this field stress the unpredictability of biological research.

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CERTIFICATION SCHEMES FOR GROWING PLANTS

by

F. GLOVER, O.B.E.

(Ministry of Agriculture and Fisheries, London)

It is generally agreed that one of the essentials to the satisfactory production of horticultural crops is pure, i.e. true to type, and healthy stocks of planting material. Trueness to type is necessary because different varieties suit different conditions; some crop better than others; and of course there is the question of season, whether early, mid-season or late. But of no less importance is relative freedom from diseases, which may result from a varietal tolerance, resistance or immunity to certain diseases.

Pure, healthy stocks may already exist waiting to be acquired, and all that is necessary is to discover them and make their whereabouts known. Rarely, however, are stocks found which do not require at least a moderate amount of treatment to bring them up to a reasonable standard. The treatment may consist merely of roguing to remove plants of other varieties and diseased plants, but even this requires a good knowledge of varieties and diseases on the part of growers if success is to be attained.

At this level the introduction of certification schemes provides an opportunity to eliminate unsatisfactory stocks and to educate growers in better management of the crops from which planting material is obtained.

Really reliable stocks can, however, only be built up by special management, starting with pure, healthy parent stocks and growing them under the most suitable conditions as regards soil, climate, isolation and the prevention or control of pests and diseases. Such are the stocks of S.S. and A. certified seed potatoes, and of S.S. certified strawberry plants which originated in East Malling clonal stocks. The high standards for these certificates were adopted as a result of research and experience gained over a period of years.

At the outset, certification schemes covered purity only and were extended to include health, particularly freedom from virus diseases, as more became known about the conditions necessary for the production of healthy stocks. All the schemes were first started on a purely voluntary basis. Now, three of them are embodied in Orders made under the Destructive Insects and Pests Acts. The Wart Disease of Potatoes Order of 1941 prohibits the sale, in England and Wales, of any potatoes for planting unless they are from stocks certified under the Ministry's scheme or the comparable schemes in Scotland, Northern Ireland, Eire and the Isle of Man; and an Order, which took effect on the 1st October 1946 contains a similar prohibition in the case of strawberry plants and

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blackcurrant bushes. Both Orders make provision for the issue of licences to meet exceptional cases. Under war conditions, in order to secure the maximum potato acreage, it has been, and still is, necessary to allow the sale of much seed that is not from certified stocks.

There are in operation at the present time certification schemes for growing crops of potatoes, strawberry plants, blackcurrant bushes, raspberry plants, hop gardens, and fruit tree rootstocks. They are all based on the same general principle with a view to the issue of certificates in respect of purity and apparent freedom from diseases at the time of inspection, except the hop gardens scheme in which inspection is for disease only and the certificate does not cover variety.

The operation of these schemes requires a trained and experienced staff. All inspections have to be concentrated into the period June to September inclusive and, during recent years, the Ministry's inspectors on whom the work has fallen—a comparatively small force with many other duties—have found that period of the year to be a very strenuous time. The following figures, taken from the years 1945 or 1946, give an indication of the annual volume of the work:

Scheme	*Number of Applications*	*Acres*	*Number of Plants*	*Certified*
Growing potato crops	951	15,559	—	12,145
Strawberry plants	742	632	—	431
Blackcurrant bushes	200	—	2,844,300	2,095,000
Raspberry plants	18	24½	—	6¾
Hop gardens	84	1,175	—	778
Fruit tree rootstocks	24	24	1,184,300	—

Training courses for beginners and refresher courses for experienced inspectors are held each year, either at the East Malling Research Station or the Midland Agricultural College, where special plots of potatoes, strawberries, blackcurrants, raspberries and fruit tree rootstocks are planted for the purpose. Two or three seasons' work in the field with experienced colleagues is necessary before those new to the work are expected to carry out inspections alone. The field work is based on carefully prepared instructions which are revised each year to cover points that arise from time to time.

We can now go on to consider each scheme.

Growing Crops of Potatoes.—This scheme was introduced in 1918 in connection with the Wart Disease of Potatoes Order following the discovery that certain varieties of potatoes were immune to the disease. The Order required that approved immune varieties only should be grown on infected land and it was necessary that stocks of these varieties, true to type, should be made available. The only way to do this was to inspect

the growing crops from which seed was to be saved. Certification was therefore confined to immune varieties and purity in the first place.

In a few years' time growers found that more reliable stocks of immune than of non-immune varieties were available and they pressed for the scheme to be extended to non-immune varieties. This was done in 1924.

Until 1940, in England and Wales, the certification scheme for Growing Crops of Potatoes continued to be related to purity only, except that certificates were refused for crops so severely infected with virus disease as not to be readily identified as true to type. In that year certificates covering health as well as purity, and based on standards previously adopted in Scotland, were issued for the first time. Certificates of two higher grades are issued only for crops grown in areas approved as suitable for the production of seed potatoes. They were at first issued only to growers in Cumberland, Durham, Yorkshire, North and South Wales, Devon and Cornwall who had formed themselves into Seed Potato Growers' Associations and had adopted approved methods of production under the guidance of technical officers. More recently membership of an association had ceased to be a necessary qualification for obtaining the higher grade certificates. They are now issued for any crops found to attain the prescribed standards and grown in one of the areas officially recognised as suitable for the production of seed potatoes.

Strawberry Plants.—This scheme first came into operation in 1927. It is restricted to specified varieties but other varieties may be accepted provided that their characteristics have been officially recorded. The issue of S.S. certificates was started in 1945. For the present they are restricted to stocks of Royal Sovereign, M.40, Huxley, M.44 and Oberschlesien, M.42.

Blackcurrant Bushes.—Introduced in 1928, this scheme still provides for only one grade of certificate. Certification is, as far as possible, by groups rather than by varieties and based on the group classification adopted by the East Malling Research Station. There are four groups: (1) represented by French Black including, amongst other varieties, Black Naples, Lee's Prolific and Seabrook's Black; (2) represented by Boskoop Giant including Prince of Wales; (3) represented by Goliath including Edina and Victoria; (4) represented by Baldwin including Baldwin (Hill Top), Black Champion and Carter's Champion. Where bushes are stated by growers to be of a variety included in one or other of the groups, the name of the variety is shown in the certificate in brackets after the name of the representative of the group, thus: Goliath (Edina). In addition varieties not recognised as belonging to any of these groups are regarded as 'unclassified', e.g. Blacksmith, Cotswold Cross, Daniel's September, Davison's Eight, Mendip Cross, Raven, Wellington XXX and Westwick Choice amongst others.

Certificates are issued only in respect of two-year old or older bushes actually inspected, but they may be used up to the 31st May in the following year, in connection with the sale of cuttings taken from certified stocks and of maiden bushes grown from cuttings taken from certified stocks.

Raspberry Plants.—1944 was the year in which this scheme was commenced. It was a relatively simple scheme with one grade of certificate issued for one variety only, Norfolk Giant. Since 1946 three other varieties have been added, viz. Malling Promise, Newburgh and St. Walfried. Fruiting plantations are eligible at present, but it is intended progressively to reduce the maximum permissible age of plantations entered for certification until, eventually, cane nurseries only will be certified. The maximum age of plants accepted for inspection for 1946 is three years.

Hop Gardens.—This is a somewhat special scheme in that it is mainly for the purpose of certifying hop gardens as being free from *Verticillium* wilt of hops with the object of making known sources from which healthy cuts may be obtained. However, other diseases, particularly virus diseases, are taken into account.

The scheme was started in 1943 and certificates are not issued for rooted cuts or setts as they are called.

Fruit Tree Rootstocks.—This is the latest scheme to be added to the list, it having come into operation this year (1946). It covers seven apple rootstocks, Malling Nos. I, II, IV, VII, IX, XII and XVI, and six plum rootstocks, Myrobalan B, Marianna, Brompton, Common Plum, Damas C and Common Mussel. Certificates can be used in connection with the sale of rootstocks themselves and of the trees produced by budding or grafting scion varieties on to them. The grower is required to send to the Ministry a statement of the number of each scion variety on the different rootstocks certified, for inclusion in a Register of Certified Root Stocks.

General.—As soon as possible after inspections have been completed a register of certified stocks is published in connection with each scheme.

There is room for improvement in the schemes. After everything has been done up to the time of inspection to ensure that certificates are issued only for stocks which merit them, from that time onward the matter is largely in the hands of the holders of the certificates and the trade. Substitution and mixing of stocks can of course take place after lifting, and much harm can be done to the best of stocks by lack of care in lifting, grading and packing. Official examination just before dispatch would do much to ensure that consignments were delivered in good condition. The Northern Ireland Department of Agriculture is able to arrange for the examination of certified seed potatoes immediately before they are dispatched to this country; and in Scotland a start on a small scale, it is understood, is to be made this year with a somewhat similar arrangement, though the problem of lack of man-power may hinder its general adoption. In the case of the other schemes, it is difficult to devise any practicable procedure.

For the immediate future we are confining our activities to the inspection of the *growing crops* and we are looking forward to receiving the assistance of those who are joining the National Agricultural Advisory Service. The work repays the close attention for which it calls and is of real service to the industry.

SOME REFLECTIONS ON MACHINERY FOR FRUIT PRODUCTION

by

H. G. H. KEARNS, B.Sc., Ph.D. and O. G. DOREY, B.Sc., N.D.H.
(Long Ashton Research Station, Bristol and N.A.A.S., Wye, Kent)

Manufacturing Problems (Dr. H. G. H. Kearns)

The fruit industry in Great Britain is perhaps one of the most wealthy when judged by the potential crops that can be produced per acre. However, the total acreage is relatively small when compared to that occupied by farm crops, say some 240,000 acres is reputed to be occupied by fruit crops. Of this some 80,000 acres represents West Country farm orchards consisting of 1 to 100 trees per acre. Of the remaining acreage (160,000) only about 80,000 is reasonably well tended by owners who are likely to be sufficiently 'far seeing' or with enough capital to use mechanisation to full advantage.

This acreage does not therefore offer a very big market to the manufacturers of specialised equipment and in fact the market is likely to be saturated say within five years unless fruit growing acreage increases considerably or the ever-increasing difficulties confronting manufacturers over export starve the English fruit grower of essential equipment.

The manufacture of well-made specialised equipment can only be achieved at an economic price if the demand is sufficient to permit of the use of modern production methods. Therefore it is clear that the manufacturer can only produce a machine provided it finds extensive demand in other fruit-growing countries or has extensive use on other crops. This point must be emphasised as there is a common view that manufacturers are just obstinate in refusing to rush into production of a new machine. It must be remembered that the simple laws of supply and demand still operate in this post-war paradise.

On the other hand it is clear that many British agricultural engineers are profoundly ignorant of the problems of the fruit grower. It is evident that the engineer cannot make much progress until he puts himself in the shoes of the grower, so that he can make a correct assessment of a particular problem. Successful equipment is not developed solely on the drawing board, it is on the land. A point of difference between the British and American agricultural engineer is that the latter personally operates the machine and ascertains its faults first hand. This is reflected in the

This article is based on a discussion opened by the two authors at the Association's Conference held in London on 6th October, 1947 to introduce the subject matter of the Association's Memorandum on Machinery for Fruit Production (see *Report Annual General Meeting*, 1946, pp. 47–52).

excellent detailed work of arrangement of component parts for ease of maintenance and repair. It is abundantly clear that there is an urgent need for British manufacturers to pull up their socks over this all-important matter.

The fruit grower from the broad viewpoint is relatively well supplied with efficient equipment. He can, if he exercises care, select machinery used for other branches of agriculture that will with relatively simple modifications satisfy many of his requirements. He is not in urgent need of entirely new machines but of well-carried-out modifications to suit his particular methods of growing.

At the present time the development and production of new equipment or even modifications to existing equipment is far from easy. The manufacturer is not in the frame of mind to embark on new ventures as he has the greatest difficulty to keep his existing models of machinery in production. It is therefore unlikely that much progress will be made in the near future unless the manufacturer has his path cleared of innumerable frustrations. This point is stressed as those not familiar with present-day engineering difficulties may well wonder why efficient new machinery is not forthcoming at a time when agriculture is most anxious to purchase all types of labour-saving machinery.

The fruit grower with an orchard of about 25 to 40 acres makes the most important contribution to the English market of quantities of quality fruit. The number of fruit growers with large acreages is limited and in some instances they have a need for special equipment not suitable for the smaller man and therefore their needs require individual attention. It is important in designing machinery to cater for the majority although the minority often shout the loudest for attention. For example the owner of 200 or more acres of fruit may well be able to afford a spraying machine of a type more suitable for the contractor but hopelessly uneconomic for the 40-acre man.

The ever-increasing mechanisation of fruit farms demands the employment of a staff with the ability to operate and maintain machinery in an efficient manner. It cannot be too heavily stressed that the land is a cruel and relentless enemy of machinery and therefore every effort must be made in the design to reduce wear and corrosion. Although every care may be made to render a machine 'fool proof', much still depends on the operator to maintain efficiency over long periods. It is painfully evident that more machines used on the land are 'wrecked out' than worn out by fair 'wear and tear'.

The average worker on the fruit farm gradually acquires his mechanical knowledge at the expense of his employer—this to some extent has to be accepted in all branches of engineering. Not only does this method of self-tuition prove very expensive but it is often accompanied by some most vicious kinds of faulty workshop practice. A well-trained mechanic of tidy and methodical habits is worth his weight in gold to the grower. It is clear that improvements in equipment must be preceded or at least be

accompanied by a great improvement in the personnel who use the machines.

The system of culture of fruit has a big bearing on future developments of machinery. At the present time we have a considerable acreage of fruit, particularly apples, in which the planting distances between the trees or bushes are insufficient for the use of large machinery. This leads to the unsatisfactory procedure of trying to fit machines into a planting scheme instead of planting to fit a machine.

Changes in the cost of labour also have an influence on the type of machines used. For example the most up-to-date recommendation for planting dessert and culinary apples as bushes is 18 ft. to 24 ft. apart. This distance not only develops a large healthy bush but it also permits the best results from spraying with a manually operated broom lance. The increase in cost of labour, the desire to reduce the extremely hard work associated with manually operated spray lances and the need to speed up the spray applications has made it necessary to reduce costs. This can only be done by fully mechanising the job. A mobile machine is trailed between the rows of trees applying the wash as it travels and the only operator is the tractor driver. The wide planting distances and type of bush mentioned above are ill suited to this type of spraying.

As spraying accounts for up to 50 per cent of the yearly costs of producing a crop, it therefore seems that the layout of orchards may have to be reviewed again to suit automatic spraying machines. I am here expressing the views of the team of workers associated with spraying machinery problems at Long Ashton, and in our view fruit crops will have to be grown as hedges. With top fruit hedges should be of moderate height and width with room enough between rows to permit the easy operation of an automatic sprayer. This proposed development of spraying technique coincides with an ever-increasing interest in grassing down and gang mowing of apple orchards. Again the hedges fit well into this system of grass management.

Perhaps the most outstanding problem of fruit production that awaits attention is a scientific study of frost prevention by mechanical means. It is a problem that will require the team work of the horticulturist, the meteorologist and the engineer. It is a problem that requires prior attention. Let us hope the newly created Horticultural Department of the National Institute of Agricultural Engineering will give it early attention.

Some Growers' Needs (Mr. O. G. Dorey)

There is a considerable amount of machinery useful to the ordinary farmer which can be adapted by the fruit grower for orchard work. In the case of tractors, for example, some of the standard makes can be adapted by making them lower and incorporating modifications, such as altering the air intake and exhaust pipe. For a grower who intends to plant up to 50 acres of fruit, tractors are available to carry out his job. For the first five years any of the medium-sized tracklayers, or wheeled

tractors, will do all his cultivations, haulage of spray tackle and sundry jobs. The trees are still small and there is no difficulty in getting close up to them. From about the sixth year onwards, however, the trees begin to develop substantial size and spread, and the amount of tractor work increases considerably mainly on spraying and haulage of fruit from the orchards. As an example, on a fruit farm of just over 50 acres, hours spent on orchard operations in the seventh year from planting, were: Cultivating, 368 hours; Spraying, 234 hours; Fruit haulage (12,000 bushels), 373 hours; other jobs, 163 hours; *Total*, 1,138 hours.

The total number of tractor hours is within the scope of one tractor, but the cultivating and spraying hours are both very largely spring and summer operations, and if they are to be carried out at the proper times two tractors are necessary. As the trees grow older more tractor work is inevitable. Of the two tractors required one should preferably be a tracklayer and the other a rubber-tyred medium horse-power wheeled tractor. Both tractors need to be of low construction and incorporate the suggestions made above. The imported type of tracklayer suits the fruit grower very well and there is a fair range of medium horse-power rubber-tyred tractors.

Where a 'walk behind' tractor is used at present, a small tracklayer of 6 to 8 h.p., if available at a reasonable price, would do all the work expected of the 'walk behind' tractor and what is more, it would do better work and be far less fatiguing to the operator.

An implement badly needed on fruit farms is a good manure distributor. Most of those used for farm work are ill-adapted for orchard work and the design of existing types should be altered to make them more useful to the fruit grower. Improvements in design to reduce corrosion and allow of easy cleaning and tractor haulage are needed.

Growers are becoming increasingly interested in grassing down their orchards, as a means of preventing erosion and conserving humus. Even in the eastern counties with their low rainfall, growers are experimenting with grassing down. An essential practice in the management of grass orchards is to keep the grass cut short. The gang mower is an efficient implement and achieves this object, but on stony ground it is liable to jam, and it may be that other methods of grass cutting involving a different principle would be an improvement.

More attention has been given by manufacturers to the development of spraying machines than to any other machinery used by the fruit grower in the production of his crop. The use of good mobile spraying outfits or underground main plants has now reached a high pitch of efficiency. New methods of application using the air-flow principle (atomisation) are attracting attention, and coupled with automatic application are proving attractive to the grower as a means of saving labour. As Dr. Kearns has pointed out the development of these machines is still in the early stages and their extended use may lead to some alteration in orchard layout. If such machines are to be best used on the hedge type of layout of trees,

some serious thought must be given to the implications of this plan of tree distribution on other orchard practices. I know of one Danish grower who always plants his trees with the rows wider apart than are the trees in the rows, and insists that this is the most economical method. In view of the high cost of spraying, any development that means a reduction in this cost is bound to have considerable weight in determining the layout of the orchard.

Another orchard practice which is costly is pruning. At first sight it is difficult to see how mechanisation can be of much help here, although I do know of one grower who is thinking in terms of power-operated sécateurs. As advisory officers we should be rather sceptical of the hair clipper principle being applied to pruning, and would require a little more discrimination to be used. It is, however, in the collection and burning of prunings that mechanisation could help.

About a third of the cost of pruning is taken up by the cost of collection and disposal of the prunings. For example, in the costs of a fruit farm of over 50 acres the cost of hand labour for pruning was found to be a quarter of the total labour cost for the year on nine-year-old trees. The hand labour on pruning was £232 and of this £166 was for pruning the trees, and £66 for collection and disposal. This is for hand labour only, on partially developed trees, where the tree population per acre is low, i.e. planting distances of 18 ft. by 18 ft. and 20 ft. by 20 ft. These figures relate to the winter 1944–5, but with fully established trees at present-day wage rates, the cost would be very considerably more. Some attention should therefore be given to the development of machinery for collecting prunings and disposing of them. The pruning shredders used in America may not be suitable here and may not satisfy the pathologist. Pruning sweeps of various kinds are used in this country. It may be possible, however, to develop these further, incorporating an incinerator to burn and distribute the ashes of the prunings on the ground.

There are a number of other problems of orchard management in which investigation into fundamental matters is required before the development of machinery or equipment can very well follow. Problems such as these are weed control in orchards by spraying and irrigation. The outstanding case, however, is the prevention of frost damage. The emphasis given to this can hardly be urged too strongly. The gross receipts from one orchard I know amounted to £13,000 in 1943 and for the next three years was between £2000 to £3000 for each year. This reflects quite clearly the loss of crop to the country, and the financial difficulties involved for the fruit grower on low-lying sites.

Man's inventive genius might well be put to work on devising a mechanised aid to fruit picking. This may be asking too much, but improved ladders should be well within the scope of inventive genius, if the devising of an actual picking aid is outside it.

SOME REFLECTIONS ON MACHINERY FOR VEGETABLE PRODUCTION

by

P. H. BROWN, N.D.H.

(Provincial Horticultural Advisory Officer, N.A.A.S., Yorkshire)

THE present trend in the production of vegetables is increasingly towards the inclusion of the bulkier type of brassicas, roots and leguminous crops in the farm rotation with stock, ley and other arable crops. Since such crops can be produced more cheaply on the farm and have the advantage of serving a dual purpose as market crops or stock feed according to ruling prices and demand, it can only be a matter of time before such crops virtually disappear from the smaller market gardens.

In this way three different classes of vegetable producers are emerging: (*a*) large-scale vegetable growers—intensive producers on extensive lines of a full range of vegetable and salad crops; (*b*) market gardeners—on a small scale of very intensive production of salad and special vegetable crops, flowers and other 'luxury' and out-of-season crops, with maximum use of glasshouses, frames, cloches and other structures; (*c*) farmer-producers—extensive production of bulky types of vegetables in the farm rotation. It is desirable that machinery should be developed to meet the requirements of these three classes of producer, whose needs differ more particularly in respect of machine size and output rather than of machine type.

Objects of Mechanisation

The main objective of the producer, whatever his scale, is to bring about the greatest possible output of top quality produce at the lowest cost per ton, and to be able to market his produce in the best possible condition. Without doubt, the effective use of machinery is one of the means of assisting the realisation of these objectives.

Increased output at low cost involves the carrying out of cultural operations at the right moment, and doing this work as economically as possible. Obviously, output of work per hour is the main factor, but with shortening hours of work, no one can carry out every operation at precisely the right moment in this variable climate of ours, if he is using hand labour only.

Furthermore, quite apart from the time factor, the high cost of hand labour is becoming an increasingly serious matter. The aim should, therefore, be to provide the worker with mechanical equipment which will increase his output to the maximum but not at a machine cost disproportionate to the increase in output. The fear that mechanisation will reduce

Paper given at the Association's Conference in London in October 1947 to introduce the Association's Memorandum on Machinery for Vegetable Production (see *Annual Report*, 1947).

the labour needed in the industry is based on a fallacy. The machine can complete a larger acreage per man hour than a gang of hand labour—thus making it possible to step up the acreage under the plough and the output per acre from the larger area under cultivation. The labour hours saved are often used to better advantage, for example in the packing shed of the more progressive growers.

Mechanical Requirements for Vegetable Production

The work in vegetable growing can be broadly divided into three stages: (*a*) preparation of the soil up to drilling or planting; (*b*) cultivation from drilling or planting to maturity of the crop; (*c*) harvesting, grading and packing of the crop.

There is ample machinery of reasonable efficiency for initial soil preparation up to drilling or planting, but from this point onwards to harvesting the position leaves much to be desired, and more mechanical assistance is needed in order to keep production costs at an economic level.

The fact that the grower may be able to obtain a contractor's assistance for operations up to seed-bed preparation still further emphasises the need for assistance later on. Furthermore, the earlier operations can often wait a day or two, whereas the later ones will not await either the contractor's or grower's convenience. Each day's delay may mean increased cost and often a decreased yield.

Despite the wider range of crops in vegetable growing compared with farming, the requirements in cultivation and equipment do not differ to the same extent. It will be appropriate to review here the equipment available at the present time for the three main classes of vegetable producers: its suitability or otherwise, and any recommendations for improvement.

Large-scale Vegetable Grower.—The mechanical requirements of the large-scale grower are without doubt the greatest, and the system of mechanisation must necessarily be somewhat flexible in view of the range of crops and acreage. In the first place, improved tractors are required for initial soil preparation. These should be fitted with plough, cultivators and other tools, articulated to the tractor and with a power-lift, allowing for close working and short headlands. A medium-sized crawler-type tractor is also needed for heavier ploughing and sub-soiling.

Most cultural operations after sowing or planting call for great accuracy, reasonable speed and simplicity of operation—requirements which are not adequately met in much of the equipment at present available. The method of fitting rear-mounted tool-bars on tractors for row-crop work is unsatisfactory for vegetable growing, where 12-in. rows are common. The operator must be able to see the whole of his work, and for this purpose forward-mounted tool-bars are the only satisfactory equipment. Unfortunately few of the existing machines provide for this.

It should be possible to aim at the production of an all-purpose or universal machine for cultivation work. This has many advantages, not

the least being economy in cost of machinery. To attempt to operate a number of machines, each for one operation, is beyond the average grower's resources. On the other hand, a universal machine, capable of undertaking most normal operations should be financially practicable for any grower—even the smaller one. It would provide him with the wherewithal to carry out his work efficiently and successfully, and should present no insurmountable problem either to designer or manufacturer.

Such a universal machine should be designed for accuracy and precision of operation with a wide speed range through suitable gearing. Low speed for accuracy, coupled with multi-row operation (say 4 to 8 rows at a time), would secure economical acreage output per hour. For successful multi-row work the drilling of the crop and subsequent cultivations must be done by the same machine. In final seed-bed preparations the machine should not cause undue consolidation of the land. Accurate steering is important, and the movement of hoe blades in particular should synchronise with the movements of the machine. The tool-carriage should mount a complete range of tools and appliances to operate in a forward position and thus give an easy and clear view.

The equipment should comprise: (1) a multi-row seed drill controlled for steering and depth, and possibly providing for combine-drilling; (2) a fertiliser drill operating alone and for fertiliser placement in conjunction with other cultural operations; (3) a unit of semi-mechanical transplanters operated at slow speed; (4) a tool-bar readily adjustable for all row-crop cultivations, especially for accurate work with 12-in. *row crops* so commonly found on vegetable farms and market gardens. The importance of even depth of hoeing and cultivating must not be overlooked; provision should be made by means of independent springing to allow for independent vertical movement of each hoe blade. It is also important that the adjustment for depth can be carried out whilst the machine is moving across the field, as soil depth and type may vary in different parts of the same field; (5) a wet-spraying apparatus (operated by power take-off from the engine) for weed and pest control and suitable for either automatic spray-bar or hose and lance work. Apparatus on the 'air-flow' or compressed-air principle would avoid carrying an excessive weight of liquid on the land; (6) a mechanical duster operated by compressed air with apertures for ground cover dusting and selective work; (7) a nicotine fumigator complete with cover-dragsheet; (8) banking or ridging bodies to provide for light banking of soil for certain crops such as leeks and brassicas.

The requirements for the engine should be to provide sufficient power to propel the unit reliably and economically in the work it is designed to do. The tractor wheels should give adequate grip without packing the soil, especially for seed-bed preparation, drilling and row-crop cultivations. Given accurately controlled steering, narrow track-laying equipment would probably best fill these requirements, always remembering that the machine must be able to work in 12-in. rows.

The ease and speed by which a change of tools can be made is also important. We are all too familiar with the collection of spanners that are often necessary to undo the innumerable nuts and bolts when changing over one piece of equipment for another. Simplicity of design making use of the socket system would avoid the necessity for any nuts and bolts whatever.

Market Gardeners.—Before the war the small market gardener was hardly mechanised at all, but machinery is now being used to an increasing extent on such holdings. Two main points arise. Firstly, for some operations the small area of land does not justify capital expenditure on equipment. Secondly, if the small grower is to succeed in the future, he may have to change his type of production, specialising in high-class and out-of-season produce. He will still require mechanical aid, but of a somewhat different type and size from the large-scale vegetable grower.

Tractors for ploughing and initial soil preparation leave much to be desired, and none of the two-wheeled so-called market-garden tractors are entirely satisfactory for heavy cultivations, especially winter ploughing and sub-soiling, though they may be suitable for summer skim-ploughing and surface cultivations. A really suitable tractor for winter ploughing and sub-soiling is too expensive to justify itself on a small acreage; such work is best carried out on contract.

The amount of work from seed-drilling to harvest is considerable, but at the moment the equipment at the small grower's disposal is mostly unsatisfactory. Whether it be cultivating tackle, drills, row-crop cultivators, or pest-control equipment, the better types are too expensive and too large for him.

Unfortunately the alternative two-wheel tractors have their inherent weaknesses. The overall size and weight is necessarily limited to that which the operator can handle. This factor adversely affects wheel grip and limits the tractor's ability to undertake ploughing. Thus, whilst it may be too small to cope satisfactorily with ploughing, yet it may be too large or unwieldy for accurate row-crop work. Again, most two-wheel tractors have rigid tool-bars at the rear, with the result that when the tractor is steered in one direction, the tool-bar tends to swing in the opposite direction, thus precluding accurate and close row-crop work which would eliminate hand-hoeing.

Furthermore, a few hours behind one of the larger two-wheeled machines for both ploughing and row-crop work can be very tiring. It is well known that if a man can sit on his machine in relative comfort he will complete a far greater area of work in a given time and do it more efficiently. The position, therefore, is that even an improved two-wheeler is unlikely to meet all the small market gardener's needs.

It is considered that a universal machine of the type already described, but preferably smaller, would meet the needs of the small grower. Whether or not all the attachments mentioned would be needed depends upon the range of crops grown, but certain other requirements should be catered for such as (1) a ploughing attachment for summer skim-ploughing; (2) the

use of the machine as a general utility vehicle on the holding for light estate carting.

Farmer-Producers.—The arable farmer already possesses most of the equipment needed for vegetables. Generally speaking, tractors and ploughs are satisfactory and any improvements made in equipment for the general arable farmer should serve the needs of the farmer-producer.

On the other hand, drills, planters, cultivators and harvesting machinery could be improved. Much of his needs would be covered by the universal machine already described and the expense would be justified on a farm growing vegetables, quite apart from its additional value for root-crop work.

Production with the minimum amount of labour is the keynote here, and the two main requirements are row-crop cultivators which will reduce hand labour for weeding to a minimum and mechanical lifters for root crops.

Other Mechanical Aids

Machinery to assist production of the crop is all-important, but in future substantial advances are called for in machinery for market presentation. Machinery visualised includes improved washing-machines, for crops such as root crops, radish, celery and lettuce; drying machines for some crops; machinery for the wrapping of salads. All these operations should be carried out by one combined piece of machinery; the article passing in at one end for washing and drying and thence for wrapping and packing. Machinery for somewhat similar work is available for other industries, and the above suggestions should be practicable.

The nailing of boxes and lids is another operation which could be mechanised more often. Better transport vehicles with wheels which do not sink into the land are needed from field to packing-shed. Tracks are probably the answer here.

Horticultural produce, particularly vegetables, is heavy and every effort should be made to reduce the burden of handling packages. This may not be a simple matter, but the development of some form of mechanical loading for packed produce would greatly help in this respect.

In another direction, machinery for the composting of straw and other material is badly needed, and should include straw-cutting, wetting with a nitrogenous solution and turning the compost.

The suggestions made above are framed in terms of general principles, but the details of design and manufacture are the province of the engineer, not the horticulturist. It should be emphasised that many of the recommendations apply more especially to the large vegetable grower. Nevertheless, whilst the small market gardener could not justify the installation of large and expensive machinery, there are obvious possibilities for the small grower through growers' co-operative associations—a coming development in the interest of small growers as market standards rise and competition in production from the larger-scale men becomes more severe.

IRRIGATION OF HORTICULTURAL CROPS

by

J. RHODES, N.D.H., and E. E. SKILLMAN, B.Sc., N.D.H.

(N.A.A.S., Guildford, Surrey, and Research Station, Cheshunt, Herts.)

ALL growers appreciate the importance of an adequate water supply, particularly in an exceptionally dry season like 1947. The past season has, in fact, forcibly emphasised the need for more irrigation in this country, and also the need for more research work on a subject on which much pioneer work has been carried out by commercial growers on their own initiative. Given well-distributed summer rainfall and a good reserve of soil water, most crops will give reasonable returns. The would-be intensive grower, however, is handicapped if he is dependent solely on rainfall and unable to give supplementary water supplies at the right time. He may, for example, plan for a second crop in a soil already heavily depleted of surface water by the previous crop, and if success is to be assured, irrigation will then be desirable before sowing or planting as well as during the growing period.

Water Requirements

Some of the most critical periods for irrigation are: (*a*) preparatory to ploughing land just cleared of a leafy crop during dry weather, when inability to irrigate may mean delay in ploughing or establishment of the next crop; (*b*) dry periods with recently transplanted crops, such as brassicas or self-blanching celery; (*c*) prolonged dry periods during the growth of leafy crops. In periods of extreme drought it is easy enough to decide that any crop is likely to respond to irrigation, but the good grower must be able to judge when to withhold water as well as when to apply it. The amount and frequency of irrigation are still matters for speculation, and will perhaps always be largely dependent on the grower's personal judgment of his soil, weather and crop conditions.

Nevertheless, even in our present empirical state of knowledge of watering problems, some guidance can be given in the light of general experience. For example, a radish crop in summer is usually a 21- to 26-day crop from sowing to harvest. Therefore, if adequate water is to be given before sowing to finish the crop, it needs to fill the top six or eight inches of soil to 'field capacity'. This is the equivalent of about half to three-quarters of an inch of rain applied before sowing, but where hot, windy conditions are experienced, more would be needed. It is further

This article is based on the author's contribution given at the Association's Conference in London in October 1947 to introduce the Association's Memorandum on Irrigation of Horticultural Crops (see Report Annual General Meeting, 1945, pp. 49–57).

known that water should not be given to the growing radish crop, as it induces too much leaf development.

Again, all brassicas have a heavy water requirement. Thus, when watering a growing crop of brassicas, it is desirable to soak the top foot of soil each time, which is the equivalent of 'one inch' of water on the land. Probably four to six such waterings will be needed according to the weather.

These examples are only practical approximations, and it is probable that irrigation practice could be put on a sounder basis if we had more exact knowledge of the water demands of vegetable crops in relation to the distribution through the soil of their root systems. In any case quite other practical considerations, such as convenience and economy of labour in moving equipment, and avoiding physical damage to crops, also influence the question of how much and how often water should be applied.

Growers have become accustomed to think in terms of the 'equivalent of one inch of rainfall', i.e. approximately 22,600 gallons per acre. Such a quantity will penetrate ten to twelve inches of top soil and this corresponds to the depth to which most summer rainfall penetrates. The basis of 'one inch of rainfall' per application is, therefore, not an unreasonable one. On this basis it is not difficult to calculate the required rate of watering, which depends on the area served by a given length of line, the output of the pump and the time that the pump is running.

The automatic measurement and control of soil moisture is an essential development in irrigation practice. The introduction of soil moisture meters as a standard item of equipment in commercial irrigation should only be a matter of time. Nevertheless, its effective introduction depends on reliable meters being produced in large numbers at a much lower price than obtains at present and of their popularisation by the results of research on their use in irrigation practice under various conditions. If such an apparatus could be linked up with electric control of the water supply, where permanent lines are installed, or in soilless cultures with sub- or surface irrigation, its practical possibilities would be immense.

Horticultural crops are grown on a wide range of soils. The easily worked sands which attract the intensive cultivator present few problems in the application of irrigation water, but many other soils such as the silty types which 'pan' on the surface after rain are not particularly amenable to overhead irrigation. At any rate they need careful study if irrigation is practised, and generally require slow application to avoid surface flooding consequent on slow intake of water. The rate of application is probably less important in the later stages of the crop's growth as compaction of the surface soil, which may be serious whilst the plants are small, is often negligible when the foliage develops and takes the main weight of the falling water.

There is need for much investigation on the response of different soil types to irrigation, and for long-term studies on the influence of irrigation, not only on the soil texture but also on its chemical status. It is said by

some growers that irrigation 'sours and impoverishes the soil', but since irrigation enables cropping to be intensified and production increased, it necessarily involves heavier demands on soil nutrients. If, however, water applications are restricted to about 'one inch of rain', losses of nutrients by leaching should be negligible under most conditions.

Water and Nutrient Supply

There are many problems associated with the water itself and the subjects of aeration and temperature control need investigation. However, of all the aspects concerning the water it is probable that the incorporation of nutrients in the irrigation water has aroused the greatest interest. Spraying the foliage of crops to correct deficiencies of certain minor elements is now an established practice, and although for some crops and circumstances the normal methods of correction by spraying the affected crop with a specific solution of the required chemical may have to be used it is obvious that where the land is served by an irrigation system there is to hand an efficient means of applying the salts in solution to market-garden crops.

With overhead irrigation the fact of extreme dilution should not be overlooked. If, for example, magnesium sulphate is being applied as a 2% solution by normal spraying methods, probably 150 to 300 gallons per acre will be used, but the quantity of liquid used through the irrigation system will be far greater than that and the salts must, therefore, be added in minute quantities. In any case to have the crops sprayed slowly for several hours with a much weaker solution may be a better method of getting the nutrients into the leaves. Even for some of the major elements Mr. F. A. Secrett, when, for example, applying nitrate of potash, uses dilutions of the order of one part in 20,000 or more of water. He has been a user of nutrient solutions in irrigation water for many years. His earlier installation picked up the concentrate by a Venturi tube, whilst his present plant uses a hydrostat, whereby a much more accurate control of concentration is possible.

Simpler and cheaper, though possibly less accurate, devices for adding nutrients have been produced and will no doubt be followed by others. One that appeals to many is an elaboration of an oscillator worked by the same means. At present the oscillator nutrient pump will only work effectively on lines up to 200 ft. and at not less than 50 lb. pressure. Such pressures are not always available from mains supplies or on glasshouse nurseries unless booster pumps are installed. One small prototype seen recently has been designed for adding chemical steriliser to the water flowing from a glasshouse standpipe with a head of about 25 ft. When the apparatus was tested, there was a loss of about 60% in the rate of flow of the mixture. There is at least one larger model now on the market for adding nutrient solutions, and this one is distinctly promising. More research is, however, required on the design of such apparatus for running off a hose or main without undue loss of pressure (Fig. 16).

Open Land Irrigation

In advising growers on the installation of irrigation equipment, we are constantly meeting with direct questions on the most efficient layout and the costs. The 'cost per acre' is the total cost of the installation divided by the total number of acres which it serves: thus the smaller units are usually relatively more costly to install than large ones. To advise on costs is difficult at present as most installations were fitted up prior to 1940. Some growers installed their equipment 10 or 12 years ago at costs of £30 to £40 per acre, if deep well boring was not necessary. The present cost would be well over £100 per acre, even where the water is taken from a stream and no well boring is involved.

The problem of the system which should be recommended for any given farm or market garden depends on the site and, of course, the depth of the grower's pocket. If the holding is on a steep slope and the lower land requires to be irrigated, with the source of water a well at the farm on top of the hill, there is no reason, given sufficient flow and a main of large enough diameter, why spraylines could not be served by gravity pressure alone. But if the water supply is near to or below the level of the land to be irrigated, then the water must obviously be pumped round, and it is here that the cost begins to mount up.

The question is frequently asked whether rotary rainers or spraylines should be used. Undoubtedly the parallel lines watering parallel rectangles give the most accurate possible cover of the land, but the cost is more than that of rotary rainers. The latter are designed to work in a series of overlapping circles which should give a fair cover to the land, but owing to the height to which the water is thrown even a light breeze converts the 'circles' into ellipses with an increased unevenness of application.

For farm crops such as sugar beet, mangolds, fodder crops, potatoes and grassland, the rotary rainer provides the cheapest method of applying water. It is run from a centrifugal pump, generally powered by a Diesel engine and applies the water in a quarter to half the time that the average sprayline takes. As has been pointed out, distribution in windy weather may result in temporary flooding of a proportion of the area covered. This is not so serious with farm crops as it is with market-garden crops, but it is clearly undesirable for soil to receive water more quickly than it can absorb it. In spite of this the attraction of the lower cost and ease of moving has led many growers to consider this type of equipment (Figs. 17–19).

Another question which is frequently asked is whether an irrigation system should be run from portable or permanent mains. The answer depends entirely on the cropping. If quick-maturing market-garden crops are to be grown, in very dry weather water may need to be applied once weekly. For this a permanent main is clearly advantageous. But if a main is only needed say once in three or four weeks, then obviously this is in favour of its being portable. For fruit crops the portable main would

probably be most suitable. Portable mains should preferably be fitted with quick coupling, and this increases the cost. One firm has introduced quick coupling 3-in. and 4-in. main in aluminium alloy, a 16-ft. length of which weighs only 35 lb., including couplings in the 4-in. size.

The answer to all 'main' problems would be to suspend spraylines from pylons built at the side of the field, but the cost at the present time would be prohibitive. In the U.S.A. permanent overhead spraylines, slung from permanent supports running across the field, are commonly installed.

On the optimum length of spraylines, several cases have been encountered in which growers have purchased spraylines, often second-hand, or have made up their own and tried to use it in lengths too great for efficient watering. When any size of piping is drilled with holes and water passed through it, there must be some variation in flow from holes at the standpipe end and holes at the distal end. The greater the length of line, and the smaller its diameter, the greater is this variation. Merely increasing the pressure will not alter that variation. In other words, an uneven distribution of water cannot be corrected by increasing the pumping pressure. The alternatives are: (*a*) to shorten the line, i.e. to have a second line served from the far end of the field; (*b*) to reduce the size of the apertures; or (*c*) to have larger diameter lines.

With regard to the advisability of using oscillators, there have been substantial improvements in design in the last ten years, but there is still room for improvement. There are complaints, even with the newest designs, about spraylines sticking with subsequent flooding of a strip of the land. They work well on short lines, but they are not infallible on the commercial lines of 250 ft. or more. There is also a tendency for certain types of coupling to become disconnected. Oscillators absorb quite a lot of pressure in working, and their substantial cost is a consideration.

Some provision for coping with wind is made through an adjustment of the oscillator, whereby the line can be made to turn through 110° in three different positions, but no mechanical design will replace the need for hand adjustment under certain conditions. The fan sprayer has much to commend it for small-scale work, since it is readily portable and simple manipulation of nozzles makes it possible to cover different sized rectangles.

Glasshouse Irrigation

With steadily mounting labour costs, interest in automatic irrigation of glasshouses is increasing. In parts of East Yorkshire one sprayline to each span of the Dutch type structure is becoming standard equipment where early lettuce are the principal crop. This system is spreading to the vinery type house in which two rows of lines are fitted. The nozzles used there are of different design from the single aperture diffuser type, and throw a flat circle of water which in falling covers a circle between 10 and 12 feet in diameter, applying an inch of water in less than an hour at a mains pressure of 35 to 40 lb. Both types are useful for winter flooding and overhead damping of crops, and in the north-east, lettuce are entirely

watered by this method, receiving in some cases as much as 12 in. of water throughout their growing season. But the extent to which the sprayline can replace the hosepipe for tomatoes and cucumbers has yet to be determined.

Fruit Irrigation

It may be very many years before there is another such opportunity as occurred in 1947 to test the effect of irrigation on fruit crops. Spray and furrow irrigation of top fruit is widely practised in drier climates than that of Britain. The trouble in 1947 was either inability to get the necessary plant, or else the failure of the water supply.

An example of an area where fruit irrigation could be practised to good effect is the Stour Valley in Suffolk. Here the river has carried to the sea millions of gallons of water, all within easy reach of orchard-covered slopes which in 1947 suffered severely from the effects of drought. Furrow irrigation might have answered the purpose here, the water being pumped up the slopes and allowed to flow back through the rows of trees by gravity. For orchards less favourably placed, spraylines fitted with coarse circular or diffuser type nozzles would have to be used. One line of these, placed near soil level between two rows of trees, will throw a jet which need not touch the branches if they are in normal positions, and would apply water in adequate quantity to the feeding roots.

RECENT DEVELOPMENTS IN INSECTICIDES AND FUNGICIDES PART II

by

HUBERT MARTIN, D.Sc., F.R.I.C.
(Long Ashton Research Station, Bristol)

ALTHOUGH it is only a year since I last reviewed my subject (11)[1] developments have been so rapid that I had no hesitation in accepting the invitation to describe to you the more recent work. There is admittedly a danger that this work is too new to be viewed in proper perspective and that it may not be confirmed by further experiment. Hence, for these or other reasons, the use in actual practice of new materials or methods may not materialise. But growers nowadays are so watchful and up-to-date that questions are sure to be asked concerning the materials now under test, and this is my excuse for dealing with some, at least, of the newer materials though I will indicate as far as I can those developments which seem likely to mature rapidly to general application and those which are likely to remain of academic interest for some time to come.

Insecticides

Chlorinated hydrocarbons.—There is little to add to the volumes already written on DDT but further work has done much to allay the fears that the widespread use of this insecticide would have a dire effect upon 'the natural equilibrium between the insect host and its natural enemies on the one hand and between fruit production and pollinators on the other' (5). Way and Synge (17) showed that the risk of injury to bees visiting blossom sprayed with DDT is slight and that they are unharmed by visiting open blossom which has been sprayed at the pink bud stage. Nevertheless it would still be wise to avoid the application of DDT to insect-pollinated crops near blossom time for the insecticidal residue would doubtless kill many of the smaller pollinating insects which, unlike bees, wander over the plant surface. The possible risk to beneficial insects likewise seems to have been exaggerated. In New York State, where DDT has practically eliminated codling moth, Harman (6) and the country agents are unanimous in their view that the increase in red mite infestation experienced in that State has little to do with the introduction of DDT. Recent correspondence in the horticultural press in this country also throws doubts on the conclusion that fruit tree red spider is encouraged by DDT. Hey (7) said that the available evidence goes to show that DDT does not induce red spider

[1] Part I is printed on pages 79–84. Part II deals with developments in 1946–7.

if applied before blossoming but advised growers who use DDT post-blossom to take precautions to control the spider attack which might appear. On the plots at Long Ashton, where DDT is not applied post-blossom, it is long odds against chance being the cause of the greater prevalence of both red spider and woolly aphis on those plots receiving pre-blossom DDT . Under Long Ashton conditions, at any rate, we must be prepared for an enhanced red spider attack on trees receiving DDT at any stage.

Returning to the effects of DDT on agriculture it may indeed be claimed that because lead arsenate has been superseded by DDT for caterpillar control, the bee-keeper is now much less liable to suffer loss of the bees through the incorrect use of insecticides. DDT can, in fact, be used pre-blossom on apple as a substitute for winter washes for it can give a complete control of aphis, capsid and winter moth and a partial control of sucker. But because of the seriousness of red spider it is unwise to omit a winter or delayed dormant petroleum oil spray, which is one good reason why the abandonment of the established winter wash programme is not generally to be recommended.

Benzene hexachloride, likewise, is a most effective tar oil substitute for use in the spring washes, but Way and Synge (17) have shown that it is much more dangerous to bees than DDT. To date the widest use of benzene hexachloride, in this country, has been as a soil insecticide and against flea beetle on seedling crops. Care must however be taken not to use too heavy an application or too high a benzene hexachloride concentration and to use the insecticide only on the crops for which it is recommended otherwise its tainting propensities may cause trouble.

With both DDT and benzene hexachloride, a question still unanswered concerns the risk of spray residues to man and stock. Clearly this problem can be solved only by long-term experiment to check the possibility of cumulative action. Until proved safe it is wise to avoid the use of either insecticide near harvest. An interesting development is that DDD (bis(4-chlorophenyl) dichloroethane, cf. DDT which is bis(4-chlorophenyl) trichloroethane) is claimed to be less poisonous than DDT to warm-blooded animals and has, for this reason, been introduced on the American market. DDD is, however, more specific in action than DDT and approaches the latter in insecticidal potency only against certain insects. The same failing seems to be shared by other newly introduced insecticides of the chlorinated hydrocarbon class. For example, chlordane, which is the name given by the U.S. Dept. of Agriculture to the active components of Velsicol 1068 and Octaklor, though highly insecticidal to most insects, proved useless against *Aphis pomi* when used as an alternative to tar-oil washes. Until specific uses for these newer insecticides are found for which they are better than DDT or benzene hexachloride, it seems unnecessary to go further into their chemistry and properties. They are, however, of considerable theoretical interest, for all share the property of ready

PLATE IX (R. B. DAWSON)

FIG. 20. KNAPSACK SPRAYER WITH HORIZONTAL LANCE FOR WEEDY TURF

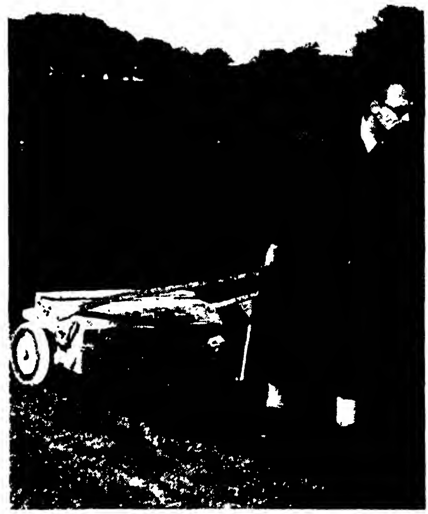

FIG. 21. FERTILISER DISTRIBUTOR APPLIES DUST TO LAWN

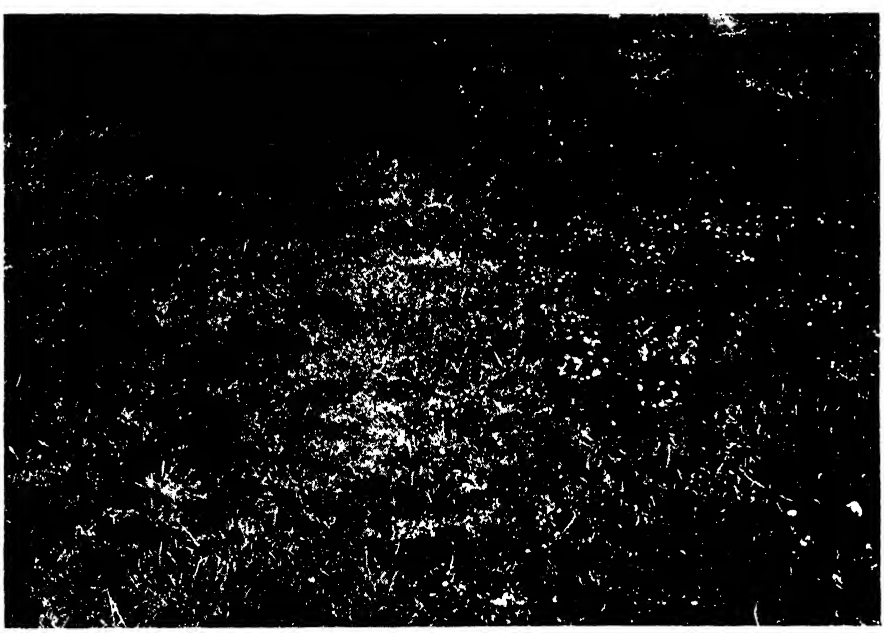

FIG. 22. EFFECT OF METHOXONE AND 2 : 4 D ON WEEDS
Front Left: Methoxone *Back Left:* 2:4 D
(4 weeks after treatment)

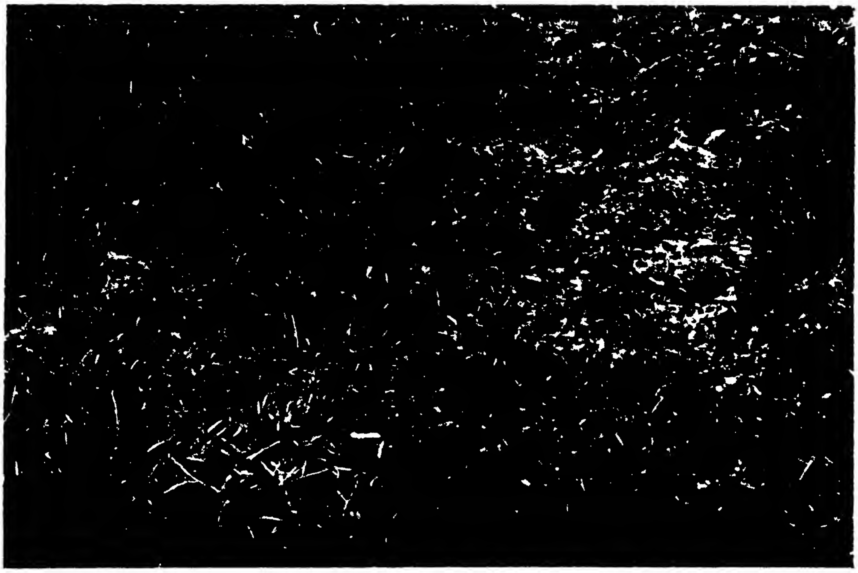

FIG. 23. CONTROL OF CATSEAR WITH METHOXONE
Left: sprayed *Right:* unsprayed

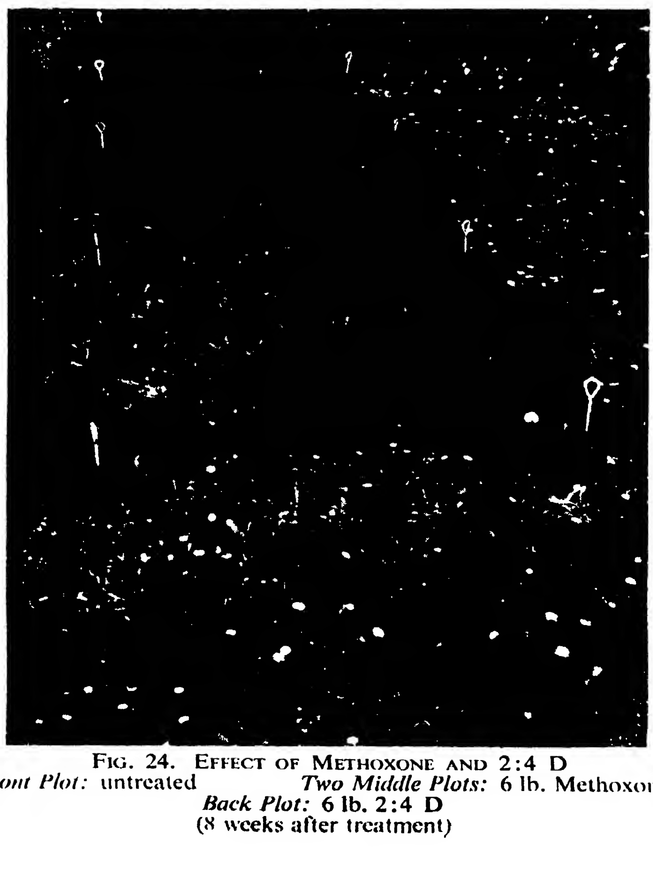

FIG. 24. EFFECT OF METHOXONE AND 2:4 D
Front Plot: untreated *Two Middle Plots:* 6 lb. Methoxone
Back Plot: 6 lb. 2:4 D
(8 weeks after treatment)

dehydrochlorination, a property which Wain and I (12) suggested in the early days of DDT was a requisite for insecticidal action among the non-volatile chlorinated hydrocarbons.

Organic Phosphorus Insecticides.—For several years nicotine has been in short supply and, with the reduction of tobacco imports, the necessity for finding a substitute has become more acute. The need is largely met by the German product "Bladan" of which the active ingredient is a complex phosphoric acid ester, hexaethyl tetraphosphate. The structure of this compound is not known with certainty but it is usually regarded as $OP(O.PO.(OC_2H_5)_2)_3$. As batches of the compound made by various methods do not differ materially either in insecticidal potency or in stability, this chemical uncertainty becomes less serious. Stability is a useful criterion for constancy of composition for, in the presence of water, hexaethyl tetraphosphate decomposes (hydrolyses) to non-insecticidal compounds. If two batches have the same speed of hydrolysis they are similar chemically and biologically. Again the precise chemical changes involved in this hydrolysis are unknown and it is possible that the insecticide proper is an intermediate product. Fortunately the rate of hydrolysis is slow and, at the spray strength recommended, 0·06 per cent (compare nicotine, 0·05 per cent), the resultant loss of toxicity is serious only after 24 hours, unless an alkali such as soap is present when hydrolysis is speeded up. A non-alkaline wetter is required and the compound has so far been available to growers only as a compounded product containing a suitable wetter. This mixture has given most effective results against all the aphides so far tested. It is also highly poisonous to man and stock but, because of the slow hydrolysis, there is little risk of persistent or dangerous spray residues. In this respect it is very similar in use to nicotine which is likewise a highly poisonous compound, but with nicotine the reason for the non-persistent and non-poisonous spray residue is its volatility. It would, however, be unwise to suggest without trial that hexaethyl tetraphosphate would be a satisfactory substitute for nicotine in apple sawfly control. Unfortunately apple sawfly has been scarce at Long Ashton since the 1945 frost so no trial has yet been made but, against this pest, nicotine seems to be effective because it is fixed by the sawfly egg or by adjacent plant tissue so forming a spray residue which apparently kills by a stomach-poison action. It is perhaps unlikely that hexaethyl tetraphosphate would be similarly fixed.

The American evidence that hexaethyl tetraphosphate is an effective acaricide suggests its use against fruit tree red spider but its value is not easy to assess, for practical control of this pest is dependent more on thoroughness of application than on specific toxicity. It is, for example, possible to control the spider with a weak acaricide such as derris root provided enough, say 2000 gal./acre, is applied.

The discovery of the insecticidal properties of hexaethyl tetraphosphate is due to Schrader, the leader of a team of workers at I.G. Leverkusen of Elberfeld, who has systematically examined the biological properties of

organic phosphorus compounds. Their search of the literature led to a previously described tetraethyl pyrophosphate, $(C_2H_5O)_2.PO.O.PO.(OC_2H_5)_2$, which the biologist, Kükenthal, found highly toxic to aphides, but this compound was considered too rapidly hydrolysed to warrant commercial development as a nicotine substitute. Trials of this compound are, however, being continued in the States.

Of the numerous phosphorus-containing insecticides discovered by Schrader and Kükenthal, many are so highly poisonous to man that their use for pest control would probably be dangerous. But some general rules emerged by which it was possible to lessen poisonous properties without important loss of insecticidal properties. The esters of thiophosphoric acid were, for example, often found less dangerous than the corresponding phosphoric ester. One such compound, *p*-nitrophenyl diethyl thiophosphate, $4\text{-}NO_2.C_6H_4O.PS.(OC_2H_5)_2$, conveniently referred to by Schrader's code-number E605, has shown such extreme potency as ovicide, stomach poison or contact insecticide that its development in this country for pest control purposes cannot be long delayed.

Systemic Insecticides.—Perhaps the most surprising of Schrader's results is the discovery that certain water-soluble compounds, if applied to the soil in which plants are growing, are taken up by the plants rendering them resistant to insect attack. This type of action may be referred to as a systemic insecticidal action. Schrader found that this property was shown not only by certain derivatives of phosphoric acid such as bis(dimethylamino)-phosphoryl fluoride, $((CH_3)_2N)_2POF$, but by other fluorine compounds. One of the latter, bis(β-fluorethoxy)-methane, $CH_2(OCH_2CH_2F)_2$, kindly supplied by Dr. B. C. Saunders of Cambridge, and listed by Schrader as a compound exhibiting systemic properties to a lesser degree than the above-mentioned compounds, has been tested at Long Ashton. Half-grown cauliflower plants growing in 8-in. pots remained free from cabbage caterpillars for some 4 weeks after treatment with the fluorethoxymethane at the rate of 1 c.c. per pot, in spite of repeated transference of caterpillars to the plants. Egg masses of *Pieris brassicae* and the single eggs of *P. rapi* were laid indiscriminately on treated and untreated plants, but the newly emerged caterpillars died on the treated plants. Although the practical value of such systemic insecticides is, with present compounds, severely limited by their intense poisonous properties, for the treated plant is rendered toxic to man and stock, their discovery is of high academic interest.

Fungicides

In spite of the ready availability and cheapness of the copper and sulphur fungicides, progress on other types of fungicide has been steadily maintained. It is, however, clear that an expensive substitute can survive only if it is free from certain defects of the established material. Bordeaux mixture, for example, has the following demerits: (1) the heavy wear which the grit, invariably present in the lime used for its manufacture, has on spray pumps; (2) the spray damage it causes to copper- and to lime-

sensitive crop plants; (3) the copper-containing spray residue may give rise to storage problems.

Bordeaux Substitutes.—The heavy wear of Bordeaux mixture is satisfactorily avoided by the use of dispersible cuprous oxide or copper oxychlorides of which several are now officially approved (*Agriculture*, 1947, **54**, p. 286). Attempts to avoid spray damage by using copper compounds which, though effective fungicides, do not readily yield cupric ions have not so far been successful. Copper sebacate, for example, equalled lime sulphur in the control of apple scab at concentrations which showed sufficient symptoms of copper damage to indicate that it is not free from the phytotoxic properties of the usual copper fungicides (9). Further work on the highly fungicidal and oil-soluble co-ordinated copper compounds such as the di*iso*propyl salicylate (8) has been held up by the lack of academic knowledge of the chemistry of these compounds which is obscure and far from straightforward, for it would be foolish to embark on extended biological work with compounds of uncertain chemical character and reproducibility.

Dithiocarbamates.—Difficulties of copper-containing spray residues appear prominently in the control of *Pseudopeziza ribis* on blackcurrants intended for syrup manufacture. Control of this disease would be greatly improved if the fungicide could be applied prior to harvesting. But because a trace of copper on the picked currants would hasten the destruction of Vitamin C in the syrup, the pre-harvest spray cannot contain copper. Trials by Marsh and others (10, 1) showed that ferric dimethyldithiocarbamate gives an effective control of this disease without leaving a residue harmful to the Vitamin C content of the stored pulp. Unfortunately the flavour of stored canned currants was seriously affected when unaltered dithiocarbamate spray residues reacted with the metal of the can. In the processing of blackcurrants for syrup and jam manufacture, the residue would be decomposed by heat and so would not be objectionable. But if the canning of whole blackcurrants in syrup were resumed, dithiocarbamate residues on such fruit would be deleterious.

The dithiocarbamates and the related thuriam sulphides have been widely tested and used as fungicides, and now form the active components of many proprietary fungicides with a variety of names. Tetramethylthuriam disulphide, $(CH_3)_2N.CS.S.S.CS.N(CH_3)_2$, appears in the seed disinfectants Nomersan, Arasan and Thiosan and in the foliage protectant Pomasol. The foliage protectants Fermate and Zerlate contain ferric and zinc dimethyl dithiocarbamates respectively and Dithane contains the interesting disodium ethylene bisdithiocarbamate which, though freely water-soluble, is a successful protective fungicide against early blight of potato. Successful reports of the use of these fungicides against apple scab from the States and more recently from the Continent naturally led to their trial for this purpose at East Malling and at Long Ashton. But at neither centre have the results been encouraging. Ferric dimethyldithiocarbamate cannot be used when the fruitlets are developing for it leaves

a tenacious and disfiguring deposit; tetramethylthiuram disulphide has given erratic results (15, 2, 9).

Glyoxalidines.—An interesting group of newly discovered fungicides containing neither sulphur nor copper are the glyoxalidines investigated at the Boyce Thompson Institute (18). The particular compound examined by Marsh at Long Ashton in 1947 was the 2-heptadecyl glyoxalidine. In its first year's trials it has given an excellent control both of apple scab and of *Pseudopeziza ribis* without a trace of spray damage, but it should be remembered that the weather conditions that year have not provided a very stringent test of a protective fungicide. The glyoxalidine is somewhat unstable, being slowly hydrolysed to N-(2-aminoethyl) stearamide (a derivative of stearic acid, a name more familiar than glyoxalidine):

$$C_{17}H_{35}C\begin{matrix} \nearrow N - CH_2 \\ \qquad\qquad / \\ \searrow NH - CH_2 \end{matrix} \xrightarrow{H_2O} C_{17}H_{35}.CO.NH.CH_2.CH_2.NH_2$$

Indeed this reaction occurred in certain preparations of the compound which failed in field trial in 1946 in the States, an indication that the hydrolysis products are poor fungicides. It is therefore somewhat surprising from the chemical point of view that the heptadecyl glyoxalidine proved an effective protective fungicide. But even if further trial shows it to be so, it is rather doubtful whether the glyoxalidines can be much used in this country for, as with the Dithane already mentioned, a compound necessary for its manufacture is ethylene diamine, an intermediate which at present has to be imported.

Organic Mercury Compounds.—A fungicide which has been extensively tried by growers against apple scab is Venturicide, a proprietary product containing phenyl mercury chloride, a fungicide of extreme potency. This year again it has given, in growers' trials, most successful results, especially on Bramley in Ulster. But at Long Ashton spray damage has again followed the use of sprays based on phenyl mercury chloride. It should, however, be pointed out that the products examined at Long Ashton were experimental, containing carriers for the mercurial other than the china clay present in Venturicide. Although the damage was undoubtedly associated with the experimental methods of compounding, the evidence showed that under certain circumstances still not fully known, phenyl mercury chloride is itself phytotoxic. Hence it is still not possible to give an unqualified recommendation of Venturicide though generally it has given excellent results.

Antibiotics.—Whether it is practical to use, as a fungicide, an antibiotic produced by another fungus is an interesting speculation which began in the demonstration that the failure of conifers on Wareham Heath is due to certain toxic substances produced by biological agencies (16). The source of these toxic substances was found to be certain fungi from which two biologically active compounds, gliotoxin and viridin, have since been isolated at the I.C.I. Butterworth Laboratories (3, 4). These compounds

strongly inhibit the growth of a wide range of fungi, including the mycorrhizal fungi essential for the growth of the Wareham Heath conifers. Can they also be used against pathogenic soil fungi? Clearly it is unnecessary to isolate and use the individual compounds if the gliotoxin- or viridin-producing fungi can be grown in the soil. For this purpose Marsh is using the fungus *Trichoderma viridi*, which produces both antibiotics, in trials against *Armillaria mellea* and his problem is reduced to rendering soil conditions suitable for the growth of *T. viridi*. It is too early to judge the success of the experiment but Marsh and I share an uneasy feeling that, before *T. viridi* can make its presence felt, it may be necessary to reduce the fertility of the *Armillaria*-infested soil to the level of that of Wareham Heath!

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SELECTIVE WEEDKILLERS FOR THE CONTROL OF WEEDS IN TURF

by

R. B. DAWSON, M.Sc., F.L.S.

(Director, St. Ives Research Station, Bingley, Yorkshire)

THE control of weeds in turf, either by eradication or by management designed to prevent their occurrence, is perhaps the most universal problem in the upkeep of turf used for sport or pleasure. Broadly, turf weeds such as daisy, catsear, ribwort plantain, broad-leaved plantain, buttercup, selfheal and clover are common to turf used for a variety of purposes and growing on a wide range of soils under varied climatic conditions. It would seem, therefore, that some common factor influencing the establishment and spread of these weeds must obtain.

Weeds and the Mowing Factor

Reflection will indicate that the mowing factor operates on all forms of managed turf and the intensity and frequency of it have much to do with the spread of turf weeds. Naturally other secondary factors have an influence but above all else close mowing stands supreme. Turf weeds survive and multiply by their habit of growth; they not only escape the mower blades but they can also, despite cutting, increase either vegetatively or by seeding below the level of the sole plate.

Rosette weeds, such as daisy, ribwort plantain and catsear, grow closely pressed to the ground so escaping punishment from the mower. They produce side shoots which develop into daughter plants and thus build up groups of plants in a closely packed colony. Such weeds are aggressive in turf and the relatively large size of their leaf blades means that the grass competes on very unequal terms. Rather different are the mat weeds like creeping buttercup, clover, selfheal, yarrow, silverweed, pearlwort and mouse-ear chickweed. These weeds have the ability to adjust themselves to turf conditions by producing shortened stems and leaves, thus escaping defoliation. Furthermore they can spread by means of overground or underground runners thus extending their area of colonisation. To our list of general turf weeds must be added the weed grasses and moss.

The actual species of weed found in any given piece of turf is dependent to a considerable extent upon height of cut. A comparison of the herbage of a putting green on a golf course with that of the fairways and of the rough, clearly illustrates this point. Mowing is therefore an important factor in all considerations of weed infestation and control.

Weed-free Swards

There are two main aspects to this problem of weed control in turf. Firstly, the management of a sward that is already weed free in such a

way as to prevent invasion, and secondly the cleaning up of swards already infested with miscellaneous weeds, which process must obviously be followed up by weed prevention.

Consideration must be given first of all to the inhibition of weed invasion. Starting with a weed-free sward it is possible to maintain it in this condition by regular but not too keen mowing, and by appropriate fertiliser treatment, supplemented by compost applications to maintain a uniform surface. Lime has to be avoided, except under special conditions, whilst the control of earthworms and other pests are necessary adjuncts. Experimental plots at St. Ives, hand weeded and de-wormed in the autumn of 1929 and early spring of 1930, have been maintained in weed- and worm-free condition for a period of 17 years with no other treatment than mowing and manuring—no hand weeding!

Turning to the second point, namely, the eradication of weeds from an infested sward, it should be realised in the first place that appropriate fertiliser treatment does much to reduce weeds and can in course of time lead to complete elimination. Where the weeds are sparse, patching the infested parts with clean turf may be done or hand weeding may be undertaken. If this proves too laborious, individual weeds may be treated with corrosive chemicals or poisons. Materials like sodium chlorate, common salt, copper sulphate, arsenic acid, sodium arsenite, sulphate of iron and T.V.O. are all effective. On large areas heavily infested with weeds obviously some form of 'all-over' treatment is desirable, but since damage to grass must be avoided many of the chemicals used for spot treatment are unsuitable and more selective materials must be used.

Experimental work with arsenic acid at low concentrations as a spray and also with weak chlorate solutions shows that weed control can be obtained with these at the cost of temporary disfigurement of the turf. Applications of sulphate of iron as a dust or in solution have been extensively used for dwarf weeds though the resultant blackening of the turf is never popular.

Lawn Sands

Perhaps the most widely used material has been 'lawn sand'—usually consisting of sulphate of ammonia and sand, or sulphate of ammonia, sulphate of iron and sand. These mixtures have a selective corrosive action but at the same time encourage rapid growth of the grass. Given warm sunny weather many weeds can easily be controlled though others like plantain, catsear and some creeping weeds are liable to escape, especially under less favourable conditions. In our work we have concentrated on repeated light applications of the sulphates and found that in this way marked reduction in weeds can be achieved with minimum turf damage. Thus a mixture of

3 parts sulphate of ammonia,
1 part calcined sulphate of iron,
20 parts carrier,

when applied at 4 oz. per square yard (10–11 cwt. per acre) three or four times in a season will give satisfactory control of a number of weeds. For the more resistant types the amount of carrier may be reduced to 10 parts and such a mixture, given uniform application, can be very successful. Combinations of sulphate of ammonia, dried blood and sulphate of iron, with or without carrier admixture, have been extensively used for 'burning out' patches of pearlwort. It should be noted that in all mixtures discussed a more satisfactory result has been obtained when a finely screened compost is used as the carrier instead of sand.

Weedkillers based on sulphate of ammonia, sulphate of iron and carrier represent, of course, one type of selective weedkiller. They are perhaps more truly 'selective' than other types referred to later in that they will more readily kill daisies and pearlwort than they will plantains, but by the word 'selective' we really mean the eradication of all weeds from turf without harm to the intermingled grass species.

Growth Substances

The lawn sand type of weedkiller depends very largely on a corrosive action on the leafage of the weeds but the 'hormone' type of weedkiller, to which the term 'selective' has now been affixed, is something quite new. A number of derivatives of phenoxyacetic acid were discovered in the 1930's to have growth-regulating or hormone-like action on certain plants when used in small quantities. Later it was found that when heavier doses were applied they would kill plants selectively and a whole range of closely allied chemical compounds has been investigated. Of these, two are outstanding, namely 2 : 4-dichloro-phenoxyacetic acid (known variously as D.C.P., D.C.P.A., and 2 : 4 D) and 2-methyl-4-chloro-phenoxyacetic acid (M.C.P. or M.C.P.A.). These chemicals in suitable doses exert a selective phytocidal action through which many dicotyledonous plants are killed while many monocotyledonous plants being resistant survive. Since much of the research work on these chemicals was done in war-time and the initial emphasis was on their value in food production, it was found practicable to use them for the control for instance of weeds in corn. It is interesting to note that whilst American workers have concentrated largely on 2 : 4 D (2 : 4-dichloro-phenoxyacetic acid), in Great Britain most attention has been given to M.C.P. (2-methyl-4-chloro-phenoxyacetic acid) and in particular to the sodium salt, sometimes known as 'methoxone'. American work on the control of weeds in turf using 2 : 4 D would appear to have started in 1944 whilst little work on turf weeds with either this chemical or M.C.P. was done in this country until 1945.

Work at St. Ives Research Station

In 1945 preliminary work started at St. Ives Research Station, both 2 : 4 D and M.C.P. being employed. Since that time investigations have been proceeding continuously and preliminary reports made (6, 7).

Experimental Methods

Information on these selective weedkillers of the growth-regulating type has been gathered from plot trials, laboratory work and many field trials. The latter have taken various forms starting with simple single-plot tests building up to full-scale replicated random block layouts. Furthermore, comparisons have been made on small- and large-scale plots, some being as much as 2 acres in area.

Both M.C.P. acid and 2 : 4 D acid are insoluble in water and so derivatives of the acids are commonly used although the acids can be emulsified of course. It would seem that there is little difference between the efficiency of various derivatives such as the sodium salt, the alkyl ammonium salts and the alkyl esters, but there is always a possibility that it will be found desirable to use a particular derivative for weeds resistant to other forms. Rates of application used in experimental work have ranged from 2 to 15 lb. of the actual acid per acre.

Liquid formulations of the weedkillers have been applied as sprays, though a watering can has also been tried. For experimental work we have used a small hand sprayer or a knapsack sprayer to apply usually a volume of 100 gallons per acre, this being a convenient amount for spraying. Powder applications have been made by hand or by fertiliser distributor (Figs. 20, 21).

In our work the methods used to measure the efficiency of weed kill have taken various forms. In some of the earlier work each plot was divided into six-inch squares by means of a frame with cross-wires and every weed mapped. This method, however, was found most laborious and, of course, did not supply numerical data. A modification of the mapping technique, in which the various kinds of weed present in each six-inch square were noted without their position in the square being actually marked, proved quite successful and provided useful data for some weeds. Thus a certain weed present originally in one hundred squares might be reduced by treatment so that it was only present in five squares. The procedure, however, was not wholly satisfactory in that a given weed present originally in one hundred squares might be still represented (though to a minute extent only) in ninety-nine squares after treatment, even though it had manifestly been all but eliminated, so that the one per cent reduction suggested by the figures was wholly misleading. Much more valuable information can be gathered by a system of estimating the percentage area covered by taking a number of counts with a one-foot square frame divided by thin wires into one hundred small squares. This technique enables more numerical data to be accumulated and gives a more satisfactory picture of the effects of the treatment. It should be pointed out that whilst the main line of work was to investigate the effects on weeds, observations were also kept on the effects of these chemicals on the grass itself, and various secondary investigations to which reference will be made later have also been carried out.

In addition to the very many trials carried out by the station both at Bingley and elsewhere, series of co-operative trials have been organised throughout the country. In 1946 such trials were concentrated on M.C.P. whilst in the current year 2 : 4 D has been under test. For these trials simple four-, six- or eight-plot experiments were carried out at selected sports clubs and golf clubs by their own ground staff using materials that were kindly supplied and packed by the various trade interests. Results of these trials were reported in the form of answers to a standard questionnaire.

As a result of all this work, much useful information has accumulated as to the use of these selective weedkillers in a variety of circumstances and under practical conditions.

Practical Results

Sprays and Dusts.—It has been found that both M.C.P. and 2 : 4 D may be used advantageously for killing weeds in turf. Early work, however, showed that the rate of application required is somewhat heavier for the perennial weeds of turf than for the usual annual weeds in corn. Evidence points to the fact also that spray applications are usually more efficient than dry applications and optimum rates differ according to which is used. Furthermore weather conditions may exert a considerable influence on efficiency but it is clear that the best results are obtained on warm sunny days when there is plenty of moisture in the ground and growth is vigorous.

Table I. Effect of Weedkillers on Cricket Outfield

Treatment	*Main weeds*		
	Before	*After*	*% Control*
No treatment	25·8	26·2	0
4 lb. 2 : 4 D spray ..	25·3	2·7	89·3
4 lb. 2 : 4 D dust ..	30·9	4·3	86·1
6 lb. M.C.P. spray ..	25·8	2·6	89·9
6 lb. M.C.P. dust ..	33·5	5·6	83·3

On a sultry afternoon it was noticed in one experiment that the initial effects of the weedkiller, namely twisting and turning of the leaves, showed up within an hour of spray application. When applied as a spray under good conditions of weather and growth, 2 lb. of 2 : 4 D per acre and 5 to 6 lb. of M.C.P. per acre will ensure a satisfactory kill of many weeds. Under less favourable conditions or when powder applications are made the rates may have to be increased to 4 lb. per acre for 2 : 4 D and perhaps 8 lb. or even 10 lb. per acre for M.C.P. These figures refer, of course, to the rates considered suitable for as complete elimination as possible at one operation. There may, however, be cases where complete eradication at one attempt is not desirable. Thus where the area of ground covered by weed is great, complete control would result in a turf largely consisting of bare

ground. In such cases the application of more than one weaker dressing is to be recommended. The figures in Table I are quoted as being typical of many of those obtained in the course of this work. They were obtained on the outfield of a local cricket ground. The main weeds were daisy, dandelion, clover, broad-leaved plantain and selfheal. Fuller results are given by Escritt (7) (Fig. 22).

On the whole, the results obtained from M.C.P. and 2 : 4 D are very similar and it would perhaps be as well to catalogue more precisely the weeds likely to be controlled. The following weeds are susceptible to treatment by either material: catsear, dandelion, hawkbits, five species of plantain (i.e. broad-leaved, ribwort, hoary, sea and buck's-horn), sheep's sorrel, ladies mantle, selfheal, mouse-ear chickweed, heath bedstraw and bird's-foot trefoil. On the other hand there are some weeds which in the present state of our knowledge would seem to be more susceptible to one than to the other. For example, buttercups appear to be sensitive to M.C.P. but often resist 2 : 4 D completely. Completely successful results against daisies are not always obtained but on balance it would seem that 2 : 4 D is more consistent. In the case of pearlwort, M.C.P. gives good results whilst 2 : 4 D, even at rates which affect grass severely, has given only poor control. Neither chemical seems to give very consistent results against clover: on some plots there has been complete control with either chemical, but as with daisies there are a number of reports of poor control. Yarrow seems to be resistant to either and is especially so to powder formulations: there is no doubt that when using sprays of either M.C.P. or 2 : 4 D a marked reduction of yarrow can be brought about by single applications whilst there is some evidence that repeat applications may lead to the elimination of this weed and further work is being carried out. Moss shows littler eaction to these chemicals, and of course the weed grasses are resistant (Figs. 23–5).

Spot Treatment.—Selective weedkillers may also be used for spot treatment of isolated weeds, the quantity required per weed being very small indeed. Thus, using a 5% M.C.P. dust less than 1 oz. is required for the whole of a square yard, so that in treating individual weeds dilution with sand is very desirable even if only for economy. For large areas a more effective method is to use a knapsack sprayer fitted with trigger release grip and to spray momentarily the isolated weeds. In this way large areas of ground can be quickly covered using minimum amounts of material.

Rates have been given in pounds of active principle per acre. Obviously such rates are impracticable for direct application and the chemicals are sold in prepared powders or solutions. The powders may be applied by hand or by efficient fertiliser distributor either directly or bulked with further carrier. Liquids are diluted for spraying and applied by means of suitable spraying tackle. For small confined areas a watering can may be used provided sufficient dilution is made but it gives rather poorer results than a proper sprayer. For somewhat bigger areas a knapsack sprayer with

horizontal lance attachment may be used—or even a stirrup pump. Larger areas such as sports fields call for bigger equipment and the ordinary agricultural type of spraying machinery will do the job quite well. Our trials have been based on a hundred gallons of liquid per acre as being a normal amount to spray. Agricultural sprayers may apply anywhere from 50 to 100 gallons per acre and trials have shown little difference in efficiency between say 50 gallons of 1·2% solution and 100 gallons of 0·6% solution, i.e. within the limits mentioned it does not matter much what quantity of water goes on so long as the appropriate amount of active principle is applied. Dilutions much above this (as required for watering can application) are less efficient, whilst with dilutions much below this there is evidence to suggest that lower rates of active principle may be adequate. To obtain much lower rates of application use of air-flow (atomising) sprays is required and these are capable of putting on 10 to 12 gallons per acre or even less very evenly.

Effect of Fertilisers and Weather.—In the course of the investigations the benefits of using fertilisers in conjunction with weedkillers were investigated and in view of the importance of ensuring that the weeds are actively growing when treatment is applied it is interesting to find that pre-treatment with nitrogen a week or 10 days before applying weedkiller leads to improved results. Not only is there generally a higher percentage control, but there would seem to be a reduced check to the grass and in turn a more rapid filling in of the bare places left by the elimination of weeds. Comparisons have been made between pre-, post-, and simultaneous treatment to ascertain which is to be preferred. All the evidence available emphasises the advantages of pre-treatment with suitable fertiliser. 'Suitable fertiliser' usually means a nitrogenous one but may also mean a 'complete'. Trials on the usefulness of applying selective weedkiller mixed with fertiliser have not given very encouraging results.

Much evidence exists to show that the absorption of the growth substance is mainly through the leaves, and that quite a short time is required for an adequate amount to be taken up. Heavy rain falling shortly after application may reduce weed kill considerably, but on occasion good control has been obtained provided a period of about four hours has elapsed between application and the onset of rain. Everything points, however, to the need for warm sunny weather and best results seem to occur in late spring and early autumn, but preferably spring since the grass has a better chance to fill in.

It has already been stated that the effects on the weeds show very rapidly under favourable conditions. Similarly, under good weather conditions susceptible weeds may have gone completely after 2 to 3 weeks but more usually a period of 6 to 8 weeks is required.

Mature grass does not seem to suffer much harm when sprayed with selective weedkillers based on M.C.P. and 2 : 4 D, though there may be some slight temporary check and occasionally there is discoloration of the grass, especially if the rates suggested are exceeded; very high rates can do

more permanent harm. Fertiliser treatment prior to application reduces the slight ill effect on the grass. An interesting observation which has been made is that even when no nitrogen has been given, increased greenness of the grass has become apparent on a number of occasions several weeks after application of the weedkiller. This effect cannot yet be explained.

Effect on Germination.—Applications of the selective weedkillers to seedling grass may have very drastic and harmful effects. In this respect both 2 : 4 D and M.C.P. are equally harmful, but some interesting differences are shown in comparing the effect of the two chemicals on germinating grass seeds.

In the case of 2 : 4 D there is little apparent effect even when the seed is sown on soil treated the same day but it is clear that with M.C.P., in dry weather at any rate, the germination of grass seed is adversely affected up to 10 weeks from date of sowing. Under wet autumn conditions the danger does not prove so serious but an interval of several weeks between M.C.P. application and sowing grass seed seems desirable (Fig. 26).

In carrying out tests to study the effect of the two chemicals on the germination of grass seeds, it was observed that whilst the untreated paths between the experimental areas showed plenty of weed, the treated areas did not. The possibility of treating seed beds has not been overlooked. Owing to the prolonged inhibition of the growth of grass seed exerted by M.C.P., it is clear that a more promising line would be to try out 2 : 4 D, though actually it should be realised that in practice the majority of annual weeds likely to be present in a seed bed will not survive mowing for long. Little progress has yet been made with this line of investigation. It may in fact not be of major importance, since correct seed-bed preparations should in any case involve cultivations designed to remove germinating weeds.

Use with Composts.—Perhaps a more fruitful use for selective weedkiller lies in the possibilities of killing dormant weed seeds in compost. The use of composts in greenkeeping is a well-established practice. Composting involves top dressing the turf with finely prepared mixtures of well-decomposed manure or fine peat, loam soil and sand, the purpose being firstly to provide a vehicle for the application of concentrated fertilisers, and secondly to true up the surface of the sward so that the mower may pass over it evenly without scalping ridges or leaving uncut hollows. In practice such composts are often prepared by building heaps of soil and old manure and allowing these to stand for a period for decomposition. Dormant weed seeds are likely to persist and are thus easily introduced to the turf. To obviate this sterilisation is sometimes carried out either by means of baking or steaming. Chemical methods to date have not proved satisfactory, for instance formaldehyde at accepted rates gives poor control, whilst cresylic acid, though better, is by no means effective and suffers the disadvantage of not being sufficiently soluble. Neither of these materials is easy to use.

Recent work has shown that both M.C.P. and 2 : 4 D can be used to give freedom from gramineous and non-gramineous weed seeds in compost. In the experiments recently carried out, rates of the order of 500 to 1000 parts per million of compost have been used but further investigations are in progress to find if this rate can be reduced. Composts treated in this way would be extremely risky or quite unsuitable for potting or seed sowing, but where the material is to be used on turf any residual effects of the weedkiller are likely to be advantageous rather than otherwise. In the test referred to already, compost treated with M.C.P. or 2 : 4 D at the high rate mentioned showed weedkilling properties when applied to turf 5 to 6 weeks after treatment, but there was no damage to the grass. A study of the effect on grass seeds sown in treated compost is in progress.

A further point which is being investigated is the effect of selective weedkillers on the seed production of maturing weeds at the time of their treatment. In other words, will ripening seeds of a plant destroyed by treatment still survive and re-infect the turf the following season?

Results with Sea-marsh Turf.—In discussing specialised uses of the selective weedkillers, mention might be made of their value on sea-marsh turf. Cumberland and Lancashire sea-marsh turf taken either from the Solway Firth or from the Morecambe Bay area is much esteemed by the bowler and the demand is heavy, so much so that first-class turf is becoming increasingly scarce. Whilst extensive areas of marsh are still available the turf is often heavily infested with one or other of the sea-marsh weeds, such as sea-pink, sea milkwort, starweed (buck's-horn plantain) and sea plantain. The use of selective weedkillers for cleaning up these areas of marsh has therefore very practical possibilities. An experiment carried out by St. Ives Station in May 1947 on a sea marsh or salting at Arnside, gave the following conclusions:

1. Sea pink can be eliminated with either M.C.P. or 2 : 4 D.
2. Sea milkwort can be eradicated with M.C.P. as a spray, but M.C.P. as powder and 2 : 4 D either as powder or spray are not as effective.
3. Sea plantain (*Plantago maritima*) and starweed (*Plantago coronopus*) are susceptible to either weedkiller.

Many different investigations have come to the fore as a result of the discovery of the weedkilling effects of growth-regulating chemicals, and the work being carried out by us at Bingley is only one aspect of their use. Swarbrick, for example, refers to the potentialities of the materials in recent general reviews of growth-regulating substances in horticulture (12, 13).

Precautions in Use

Work at Bingley and elsewhere has shown the necessity for not allowing any trace of these growth-regulating chemicals to reach crops for which they are not intended! Both M.C.P. and 2 : 4 D affect a number of common plants and shrubs in addition to weeds of turf. Whether spray or

powder is used, drift must be avoided carefully. Even the vapour from some formulations may be deadly. As an example, one day during the summer of 1947 the sodium salt of 2 : 4 D was being mixed with sulphate of ammonia on a small scale for experimental purposes. The day was warm and the mixing was done on a small table more or less in the open. A nearby greenhouse door was open for ventilation and the tomatoes in it were severely affected by the vapour which drifted in. The plants were about 2 ft. high when affected and though they were not killed the crop was much reduced. The plants grew to 6 to 7 ft. high but even fruits at the top of the plant have proved to be distorted.

Costs

The question of cost is difficult at the moment. In the United States where 2 : 4 D is used extensively and M.C.P. scarcely at all, costs have become stabilised whilst lower rates of application seem to be sufficient and 1½ lb. to 2 lb. per acre of 2 : 4 D is a standard. There are many proprietary compounds of 2 : 4 D there and they have the merit of being sold with a declared 2 : 4 D content. The cost would seem to work out at 30*s*. to 50*s*. per acre, and contractors obtaining their own material at wholesale rates will carry out work for £2 to £3 per acre. In this country the position is by no means so happy; there are few products on the market and no constitution is stated other than the name of the active principle on which the product is based. The cost of these materials runs from £6 to £9 per acre while the contract price for weed eradication, i.e. supplying material and spraying it on, runs from £7 to £20 per acre depending on the area involved and the contractor.

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PLATE XI (R. B. DAWSON)

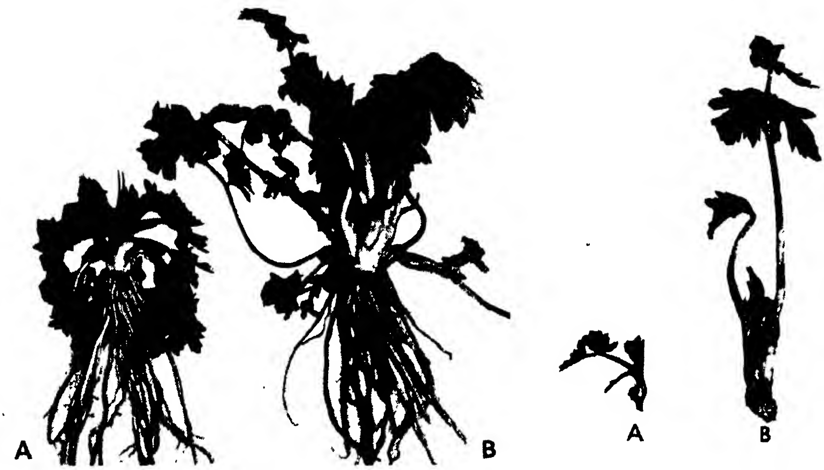


FIG. 25. METHOXONE CAUSING SWELLING OF CREEPING BUTTERCUP

A. Untreated B. Treated

(11 days after spraying)

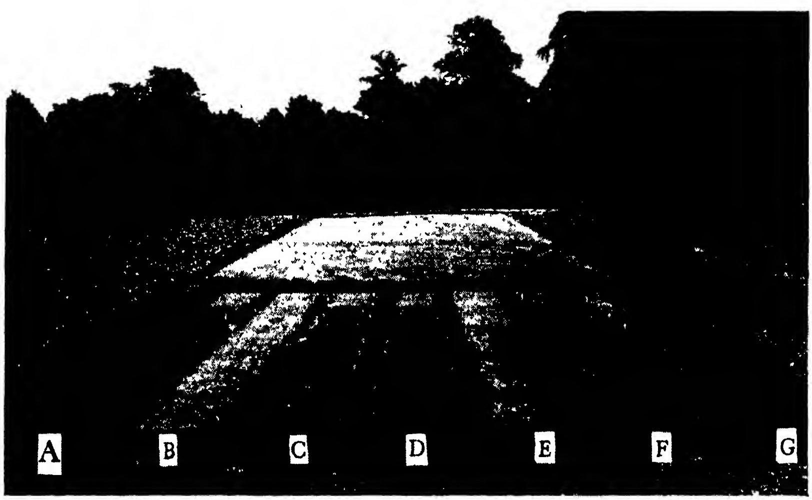


FIG. 26. EFFECT OF WEEDKILLERS ON GRASS GERMINATION

A, C, F	6 lb., 4 lb., 2 lb. of 2:4 D	Grass growing
B, E, G	6 lb., 4 lb., 2 lb. of Methoxone	Mostly bare ground
D	No treatment	Grass growing

(10 weeks after treatment)

PLATE XII (M. L. YEO)

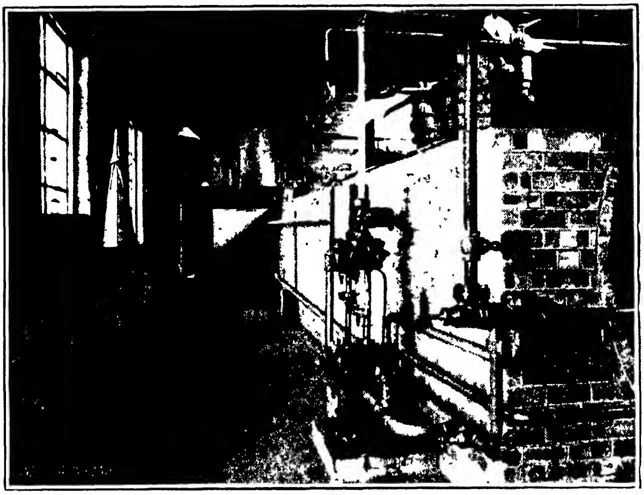


FIG. 27. CENTRAL INSTALLATION SHOWING BOILER-HOUSE WITH FEED PUMP AND INJECTOR

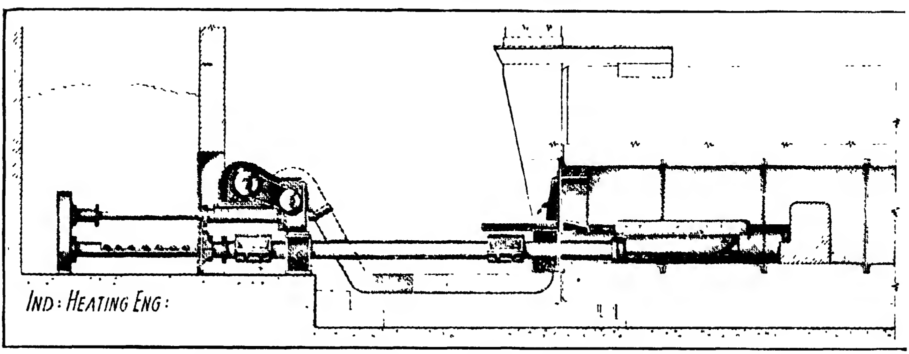


FIG. 28. SECTIONAL VIEW OF A PRIOR BUNKER-FLOW STOKER AS FITTED TO A BOILER

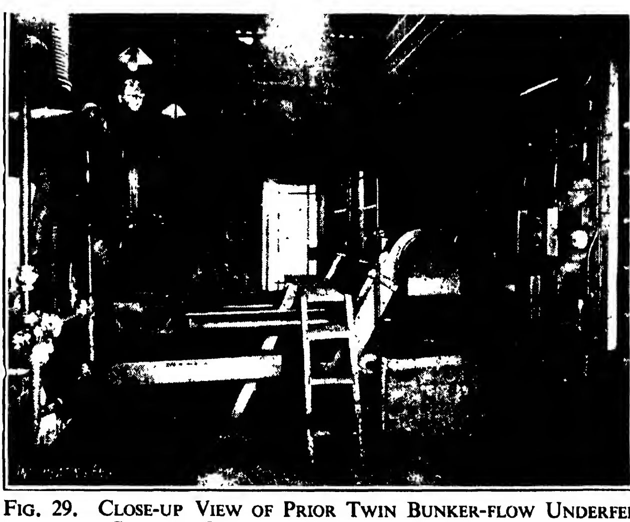


FIG. 29. CLOSE-UP VIEW OF PRIOR TWIN BUNKER-FLOW UNDERFED STOKERS FITTED TO THE LANCASHIRE BOILER

FUEL UTILISATION IN HORTICULTURE

by

MARGARITE L. YEO

(British Coal Utilisation Research Association
Leatherhead, Surrey)

THERE are many ways of approaching the problem of increased food production under existing conditions. Shortage of materials, and the necessity to make do with old glasshouses are all too familiar to all of us. It is not intended to recommend economy measures in actual crop cultivation. There are, however, methods of selecting heating systems and using fuel to the most effective and least wasteful extent which should help to meet the present difficulties.

Glasshouse Heating

There is a tendency to cling to old methods (often perhaps this is a case of necessity!) but a comparison of modern systems with those of earlier days reveals that there has been little change in basic principles. This is evident if we trace the development of the hot-water heating system through history (1, 2, 3). We find references to crop protection in the works of Columella written as far back as the first century A.D.; and Seneca describes a hot-water heating system embodying a primitive form of flash boiler. 'Plant houses' were first introduced into England by the Romans; they were of very solid brick or stone construction and had inadequate window lighting. From the seventeenth to the nineteenth century onwards, greenhouses of lighter construction were employed and cultivation was extended to a wider range of plants. Stove heating, first introduced into England in the early sixteenth century, was followed by a development of the Roman hypocaust; ducts laid beneath benches or floor carried away the hot flue gases from a hand-fired furnace at one end of the glasshouse to a chimney at the other. Very few examples of this type of heating are now to be found.

Hot-water systems grew in popularity from the beginning of the nineteenth century. The direct pipe system gave place to the low-pressure natural-circulation system, and this in turn—during the latter part of the nineteenth century—to the forced-circulation system (4–18). The high-pressure steam-cum-water system and low-pressure steam heating are more recent innovations. A wide diversity of heating systems is still used, and examples of nearly all the above types are to be found in Great Britain today.

Indoor cultivation in the old days was confined chiefly to exotic plants and glasshouse construction was inclined to be elaborate. Utility, minimum cost of production and maximum output are now the essential

considerations. How do the existing heating systems meet these requirements, and what economies have been effected? Systems are frequently installed which suffer from certain defects (e.g. a low chimney of 20 ft. with poor draught and consequent loss of boiler output). Principles of glasshouse construction and heating systems are inter-related with methods of glasshouse production. Horticultural research stations have been a great help to growers in developing cultural methods. There are now increasing opportunities for expert advice from specialist research stations dealing directly with fuel and boiler furnace problems.[1]

Hot-water Systems.—In the low-pressure system with gravity circulation a maximum flow temperature of 180°–190° F., with the return at not less than 120° F., is recommended. The maximum temperature difference of 60° F. between flow and return corresponds to an average pipe temperature of about 150° F. The Ministry of Fuel and Power recommends that the range of output for efficient working should be in the ratio 1 : 10, compared with the figure of 1 : 6 which is usual for existing installations. Development of this type of system should be along the lines of reducing the temperature difference between flow and return.

The forced circulation system has an advantage in this respect, since the temperature difference is less by 10° to 20° F. than with gravity circulation. On large nurseries the use of pumps capable of maintaining 40 to 50 ft. head of water is becoming more general, and with pumps of ample capacity a temperature difference between flow and return of 10° F. is normal. Compared with the gravity circulation system, forced circulation gives better hot-water distribution, and therefore more uniform heating (Fig. 27).

The type of boiler in use on nurseries is not critically related to specific requirements, and in hot-water systems the practice is to use sectional, horizontal or tubular boilers indiscriminately (3–12). There have been few attempts to develop boilers to meet the special requirements of nurseries, and there would seem to be ample scope for research in this field. In the steam-injection method of heating, vertical boilers are commonly used on smaller installations and Lancashire and Economic boilers on some larger ones. In deciding the size of the boiler to be installed in relation to the heating surface of the piping, a safety margin of one-third should be allowed over the rated output. In this connection it may be noted that each increase of 1° F. in the temperature of the glasshouse means a 3% to 5% rise in fuel consumption. A full account of boiler maintenance and operation has been given in Fuel Efficiency Bulletin No. 46 (6).

Firing of Boilers.—With hand firing, it is usual to bank the boiler at night, but this practice is to be deprecated as being wasteful of fuel. Another objection is the time taken each morning to regain the optimum temperature in the glasshouse after the fire has been cleaned and refuelled. Underfeed stokers and especially sprinkler stokers have given excellent

[1] Such as the Fuel Research Station, Greenwich, and the British Coal Utilisation Research Association, Leatherhead.

results. They offer the advantages of thermostatic control and are capable of firing low-grade fuels (Figs. 28, 29).

The majority of existing hand-fired boilers rely on natural draught, with the result that only a limited range of fuels can be used with success, i.e. coke for day-time heating and low-volatile coal or anthracite for banking at night. Owing to the fuel shortage, however, slack, wood and even peat and home-made briquettes have had to be used of recent years, with results which leave much to be desired.

Experiments with coke breeze have shown that this can be used very effectively for glasshouse heating with forced-draught furnaces (20), which may be fitted with thermostatic controls. One appliance of this sort employs closely spaced grill bars to avoid fuel waste into the ash-pit. Primary air is supplied by an electrically driven fan to the ash-pit, which is airtight. The grate can easily be converted to the use of anthracite or sized coke under natural-draught conditions, as it is fitted with removable bars which rest between the fixed bars.

The optimum fuel-bed thicknesses (6) for various classes of fuel are shown in Table I. In no case should fuels exceeding 6-in. cube be used, and tubular and sectional boilers should be limited to 2-in. coke cubes.

TABLE I

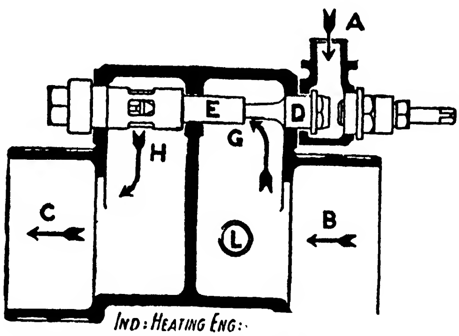
Size and type of fuel	*Suggested thickness of firebed*
Broken coal	9 in. to 15 in.
Unbroken coke	12 in. to 18 in.
Anthracite cobbles	8 in. to 12 in.
Large anthracite	10 in. to 15 in.
Large cobbles (low volatile)	10 in. to 15 in.

Successful experiments were carried out at the Cheshunt Research Station in 1931 with thermostatically controlled oil-fired heating of tomato houses (36, 37). Large-scale adoption of this type of heating is, however, ruled out on account of its high cost compared with solid-fuel firing by hand. Light oils (gas and Diesel) are more satisfactory than the heavy oils, but under existing import conditions their use is out of the question. It has been suggested that an oil-fired heater of the type that heats the air direct and not through hot water could be used effectively in a glasshouse. With such an arrangement the thermal efficiency would be as high as 95%, compared with 65% for an oil-fired sectional or tubular boiler.

Steam Heating Systems.—Steam was first used for glasshouse heating in Liverpool in 1788. Small-diameter steam pipes were used to heat air in larger concentric pipes, and the warm air was then distributed throughout the houses. Improved hot-water systems gradually supplanted steam heating, which was found to overheat and dry the air and hence retard

plant growth. This drawback was particularly evident during last century, when glasshouses in general suffered from lack of ventilation. Steam heating has been re-introduced only during the last 30 years.

The steam heating systems in use in the U.S.A. have been classified by Laurie and Kiplinger (9) who mention that a direct system operating at low pressure is now undergoing tests. On several large-scale installations in this country, steam at 30 to 100 lb. per sq. in. is passed through insulated pipes to the glasshouse, where it traverses spirals of small-diameter pipe within the usual 4-in. cast-iron circulating pipes. The temperature of the water in the latter is maintained by the latent heat of the steam condensing to water, the condensate being pumped back to the boiler-house. This system is stated to give improved circulation compared with direct heating of the hot water by a local solid-fuel furnace. Moreover, the central boiler and permanent piping can be used to supply steam for soil sterilisation *in situ*, with resultant saving in cost.



TEXT FIG. 3.—SIDE-SECTIONAL VIEW OF THE LINGFIELD HEATER-CIRCULATOR

A somewhat similar arrangement has recently been installed in 2 to 3 acres of tomato houses near Worthing, Sussex. Here the steam passes into the water system via a Lingfield heater-circulator (shown in section in Text Fig. 3), in which the ejector E creates a suction which draws water from the inlet B, fitted to the hot-water pipes, heats it by mixing with steam (delivered at A), and discharges the heated water at H into the pipe connection C. With this system the rate of circulation of the water in the heating pipes is greater than with the electrically operated pumps formerly employed. The changeover of the installation in 1946 from separate hot-water boilers to a central 30 ft. by 7 ft. Lancashire steam boiler (fitted with No. 10 Prior twin bunker flow stokers, Fig. 29) heating the glasshouses by steam injection, has effected a saving of 137 tons of fuel per annum, in spite of the severity of the winter of 1946–7. On the basis of increased prices this is equal to a saving of more than £800 per annum. Fuels such as singles and slacks can be utilised on a central installation of this kind, whereas the sectional boilers formerly employed were limited to anthracite and coke, now in relatively short supply. Here again we have an example of the

double advantage of steam heating and soil sterilisation without incurring additional expense. Operating results have fully justified capital expenditure on this new installation, and the improved heating efficiency has given a substantial increase in tomato crops together with earlier ripening.

Surplus Steam from Power Stations.—For heating glasshouses in the vicinity, this scheme has definite economic possibilities (4), as was demonstrated in Germany in 1939. The Klingenberg Station, for example, supplied about 9 tons of steam per hour at 35 lb. per sq. in. to heat glasshouses covering 160,000 sq. ft. of cultivated beds for cucumbers and tomatoes, and operating when the lowest temperature outside was −20° C. At the Weismoor Station steam was bled from the turbines (where peat fuel was used) to heat 375,000 sq. ft. of glass, and supplementary heat was supplied in the form of purified combustion gases.

Other Fuel Economy Measures.—With glasshouses in Guernsey waste heat has been recovered from flue gases by means of an improvised economiser, the gases being passed over coils of 4-in. piping through which cold water is circulated (21). The interspaces between the pipes are filled with insulating material. With this arrangement the flue-gas temperature has been reduced from 1000°F. to 200°F., and the heat recovered has been used to warm the boiler feed water. In a large vinery fitted with similar waste-heat recovery arrangements the heat loss in the flue gases was found to be less than 10%. A similar method has recently been adopted in Scotland in a vinery, using anthracite coal, and heating 1410 ft. of 4-in. piping in an area 180 ft. by 30 ft.

Insulation is receiving closer attention as an important factor in heat conservation under glass. It is calculated that 72% of the total heat loss from a glasshouse takes place through the roof, the actual rate being of the order of 7000 B.Th.U. per hour per °F. per acre. Of the remainder, 7% is through the walls and 21% through the soil. This suggests a very high percentage of total heat loss from a glasshouse on a frosty night. Experiments are in progress in which aluminium roller blinds are being prepared to reduce radiation losses through the roof at night. Other insulation tests are being carried out at the National Institute of Agricultural Engineering and elsewhere, which should all contribute to the reduction of this problem of heat loss.

Electrical Systems.—It is not intended to give details of results obtained with electrical systems, as this is a subject dealt with fully in the reports of the British Electrical and Allied Industries Research Association (22–25). In experiments now in progress at their experimental farm near Reading, the techniques of installation and operation of tubular heating, convection heating and low voltage strip heating are being studied. Suggestions have been made to utilise existing cast-iron hot-water piping for electrical heating purposes, the solid-fuel boiler being replaced by an electric boiler inside the glasshouse.

Where cost is not the primary consideration, but time and labour are of first importance, the advantage of electricity has been proved, especially

for small greenhouses, for garden frames and for soil heating. For large commercial glasshouse installations, electrical heating does not appear to be an economical proposition as yet, but in some localities there may be justification for its use during peak periods as an auxiliary to solid-fuel heating. Comparative costs of oil, coal and electricity in heating glasshouses (19) are of interest, although conditions are necessarily very variable.

Soil Sterilisation

Sterilisation by steaming has become increasingly popular, but there is still much argument as to the most successful and economic procedure. The necessary steam is usually supplied by a converted locomotive boiler or by a smaller vertical boiler with an evaporation of upwards of 450 lb. per hr., the steam pressure being not less than 80 lb. per sq. in. Reference has already been made to the use of a single steam-generating plant for both glasshouse heating and soil sterilisation, which has been proved to have an economic advantage over separate plants for the two functions (15, 16). According to Gamble (7, 8), the annual consumption of solid fuel in this country by boiler plants used solely for soil sterilisation is 50,000 tons.

The need for closer attention to the evaporative capacity of the boiler plant is stressed by Cross (18). It is often not realised how great an evaporative capacity the boiler must have in order to supply the unrestricted outlets of the type of steam grid normally employed. It is claimed by Cross that: (1) efficient boilers with larger and longer fire-boxes are required, in conjunction with a larger superficial area of grids; (2) the area which can be sterilised at one setting, using boilers of known evaporative capacity, should be more carefully studied. The objective should be to ensure the consumption of all the steam the boiler is capable of generating at a predetermined optimum pressure, which can be maintained throughout the day.

A comprehensive account of steam sterilisation is given in a recent publication of the Ministry of Agriculture and Fisheries (34), and only one or two of the more practical methods are referred to here.

In the Hoddesdon system a number of 1½-in. pipes 6 ft. to 7 ft. long are laid down and joined by flexible hoses to a header. A typical installation employs a boiler operating at 90 lb. per sq. in. and producing 2000 lb. steam per hour. The sterilising network consists of eight pipes, and the temperature of the soil is raised to 212°F. in 20 minutes provided extremes of wetness or dryness of soil are avoided. With this installation an area of 84 sq. ft. of soil can be steamed to a depth of 18 in. to 24 in. in 30 minutes. This apparatus is particularly useful in cucumber houses, using shorter pipes to suit the narrower beds.

The John Innes soil steriliser (33) consists of a brick structure, 5 ft. 2 in. by 3 ft. 3 in. in cross-section, in which the soil is placed on a perforated galvanised plate over a trough of water heated by flues carrying hot gases

from the fire. The steam is allowed to diffuse through the soil for about one hour, or until every part of the soil has reached 180°F.

In high-pressure sterilising the dry soil is riddled and deposited loosely in bins to a depth not exceeding 12 in. The steam is turned on and the temperature of 200° to 212°F. is attained in 5 to 10 minutes. The steam is then turned off and the hot soil left in the bins for 5 to 10 minutes before allowing to cool.

Soil baking is recommended only for relatively small quantities of soil used for propagating. Close temperature control of the baking process is essential, since too high a temperature may result in failure of seeds to germinate in the previously baked soil. Temperature may be raised to 180°F. and kept at this point for 10 minutes, but must not be allowed to exceed 212°F. Rapid heating and cooling are advisable.

Soil Warming and Soil-Warmed Hot-beds

In 1793 the gardener to the Earl of Derby (1) was the first to make use of steam for 'forcing' potted plants in frames. Nowadays growers frequently rely upon fermented manure for making hot-beds, but soil warming with heat from an external source is becoming increasingly popular.

The coldness of the soil at the time of planting is a handicap in the cultivation of tomatoes under glass, since root growth is thereby retarded and soil fungi encouraged. Soil warming by buried electric cables, first tried in Norway, has been found too expensive in England for commercial work. As an alternative, Bewley (36, 37) and others have been experimenting since 1927 with 1-in. hot-water pipes spaced 2 ft. to 3 ft. apart and buried at a depth of 2 ft., the hot water being supplied from a coke-fired boiler, controlled by a soil thermostat. Improved yields of cucumbers, tomatoes, and all market garden glasshouse crops have been secured by maintaining a soil temperature of 80° to 90°F. More research is needed to determine what are the optimum soil temperatures for particular crops. The London and Counties Coke Association (38) has recently published useful information about the layout of soil-warming installations, and development work is proceeding on an improved control valve for the hot-water circuits.

Experiments on electrical soil heating in frames (43–45) and under cloches (47) are in progress in this country under the direction of the British Electrical and Allied Industries Research Association. It is interesting to compare the results with those of similar tests, for example in U.S.A. (46), Canada (48), France (49).

Condenser water from power stations is used in Germany (4) for glasshouse soil heating, being circulated in pipes 4 ft. apart and about 14 in. below the surface of the soil. Beneficial results have been obtained by applying this method to tomato growing. Warm water is turned on in January at planting time, when the average temperature of the soil in the houses is only 50° to 54°F. Using condenser water at a temperature of

59° to 68°F., it is found that the soil temperature can be raised about 5·5°F. within 6 days. Experiments on the same lines have recently been carried out in the U.S.A.

Orchard Heating

A heating device which would guarantee immunity of fruit blossoms from the ravages of frost would be certain of widespread adoption, as it would insure the fruit farmer against perhaps the heaviest risk he has to face. Frost damage generally occurs between midnight and sunrise, a period in which the temperature a few feet from the ground falls sharply on account of the air here being chilled by contact with the earth, which on a clear frosty night radiates heat rapidly.

In 1936 the London and Counties Coke Association developed a portable coke-burning heater which raises the temperature of this layer of air and thus causes convection currents and mixing with the warmer air above. Forty such heaters per acre are generally sufficient for suitably sited orchards; each heater holds 42 lb. of coke, sufficient for 10 hours' unattended operation. An alternative which has been widely adopted in the U.S.A. is the use of oil heaters of about 2-gal. capacity, supplemented by some form of fan to assist the natural circulation of the air due to convection.

Farrall, Sheldon and Hansen (50) describe experiments in Michigan, U.S.A., with infra-red heating units, the object being to transmit to the plant and the surrounding earth sufficient radiant heat to offset the heat loss by radiation. Infra-red radiation from an electric heating element fitted with a reflector effectively prevented frost damage to fruit trees within an area 40 ft. square, even on the coldest nights. It was claimed that in weather conditions corresponding to late spring and early autumn a radiation intensity equivalent to 10 watts per sq. ft. is sufficient to prevent radiation frost on both thin- and broad-leaved plants. Farrall's experiments were not restricted to electric heating; he used also an oil burner to maintain a heater tube at dull red heat and directed the radiation down on to the crop by special reflectors. The unit consumed 50 gal. of kerosene during the test period of about 7½ hours, and radiated approximately 670,000 B.Th.U. per hour.

Favourable results have recently been reported with the use of jet-propulsion engines as a source of hot gases for orchard heating (52).

Conclusion

The foregoing account should be regarded as a generalised review intended more as a guide to possibilities rather than favouring any special method of heating. The advantages of overhead piping systems compared with lower piping, and other such unresolved questions, can be left to the grower and the crops to decide. The main point is that the era of cheap and abundant fuel in this country has come to an abrupt end, and with it the need for a break in the more conservative but wasteful methods of

heating has to be recognised. It is hoped that a comparison of past and existing systems, with 'fuel economy' as the keynote, may serve as a basis for forthcoming research.

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A LIST OF RECENT PUBLICATIONS ON HORTICULTURE AND ITS SCIENCES

The following publications have appeared or been notified since "A List of Recent Books on Horticulture and its Sciences" was published in Occasional Publication on Scientific Horticulture, No. 5 (March, 1947). Prices are mostly as originally announced or as since revised, but are subject to correction. The inclusion of a book in this List is no guarantee that it is still obtainable, for some of these books are known to be out of print at the present time. (N.B.—These books can be obtained through any bookseller or from the publishers: they cannot be supplied by the Horticultural Education Association.)

Cherries. N. H. GRUBB. 176 pp. illus. (London: Crosby Lockwood, 1948). 30s. 0d.

Plums of England. H. V. TAYLOR. 160 pp. illus. (London: Crosby Lockwood, 1948). 30s. 0d.

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Land and Landscape. B. COLVIN. 266 pp. illus. (London: J. Murray, 1948). 21s. 0d.

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Fruit Growing Outdoors. R. BUSH. 518 pp. illus. (London: Faber and Faber, 1947). 18s. 0d.

Harvesting and Storing Garden Fruits. R. BUSH. 162 pp. illus. (London: Faber and Faber, 1948). 12s. 6d.

Peach Orchards in England. J. BROOKE. 86 pp. illus. (London: Faber and Faber, 1947). 7s. 6d.

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Vegetable Culture. K. H. JOHNSTONE. 268 pp. illus. (London: Nelson, 1948). 7s. 6d.

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Propagation of Plants. M. G. KAINS and L. M. MCQUESTEN. 639 pp. illus. (New York: Orange Judd, 1947). 24s. 0d.

Twenty Years of Seed Research. L. V. BARTON and W. CROCKER. 170 pp. illus. (London: Faber and Faber, 1948). 21s. 0d.

The Grafter's Handbook. R. J. GARNER. 223 pp. illus. (London: Faber and Faber, 1947). 15s. 0d.

Ornamental Cherries. COLLINGWOOD INGRAM. 259 pp. illus. (London: Country Life, 1948). 30s. 0d.

New Plants of the Year. C. H. CURTIS and R. HAY. 128 pp. illus. (London: Latimer House, 1948). 15s. 0d.

Flowers: East and West. The Art of Arrangement. J. G. CONWAY. 336+vii pp. illus. (London: Routledge and Kegan Paul, 1948). 40s. 0d.

Design for a School Garden. A. W. J. YOUNG. 99 pp. illus. (Worcester: Littlebury, n.d.).

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